FINAL REPORT -

ADVANCED MISSION

ANALYSIS STUDY

For:

Jet Propulsion Laboratory
Pasadena, California

LOCKHEED • CALIFORNIA COMPANY

A DIVISION OF LOCKHEED AIRCRAFT CORPORATION

SPACECRAFT ORGANIZATION

REPORT NO. LR 17358

DATE 10-28-63

MODEL

COPY NO.

TITLE

ADVANCED MISSION ANALYSIS STUDY - FINAL REPORT

This work was performed for the Jet Propulsion Laboratory, California Institute of Technology, sponsored by the National Aeronautics and Space Administration under Contract NAS7-100.

REFERENCE

CONTRACT NUMBER(S) JPL 950579

PREPARED BY

F. E. Hoffman

J. A. Davidheiser

APPROVED BY

SUBMITTED TO: Jet Propulsion Laboratory
Pasadena, California

REVISIONS

REV. NO.	DATE	REV. BY	PAGES AFFECTED	REMARKS

FORM 402-2

TABLE OF CONTENTS

		PAGE
	TITLE PAGE	.1
	TABLE OF CONTENTS	.2
1.0	SUMMARY	1
2.0	INTRODUCTION	2
3.0	MISSION OBJECTIVES - GENERAL	3
4.0	STUDY PROCEDURE	5
5.0	MISSION ONE - JUPITER PROBE	7
	.1 Operational Modes	7
	.2 System Candidates	11
	.3 Operations Analysis	13
	.4 Vehicle Design And Analysis	16
	.5 System Definition	21
	.6 System Evaluation	24
	.61 Reliability	24
	.62 Cost	33
	.63 System Performance Index	43
	.64 Programming Variations	45
	.65 Development Plan	47
	.7 Mission Evaluation	49
6.0	RESULTS FOR OTHER MISSIONS	51
	.1 System Definition	51
	.2 Development Plans	81
7.0	SUMMARY OF MISSION EVALUATIONS	89
8.0	REFERENCES	91

N65 17523

1.0 SUMMARY

This report is a summary of the results of a study devoted to the development of a quantitative method of comparing advanced space missions for the 1970 to 1990 time period. Five advanced missions were considered and the relationships of cost, reliability, schedule and system performance were investigated.

The missions considered were:

1. Unmanned Fly-by with Entry Probe to Jupiter
2. Manned Lunar Base
3. Earth Orbiting Manned Space Station
4. Manned Mars Landing and Return
5. Unmanned Sample Return from Venus.

Although Mission One - Jupiter Probe is used to illustrate the methods developed, summary results for the other missions are included. These results include identification of long lead time development items, system description and performance required, and a summary of the mission evaluation criteria.

In general, a system performance index has been developed for selecting the best system candidate within a particular mission; this system performance index is a space oriented cost effectiveness. In addition, a Mission Evaluation Criterion has been developed, and applied to five advanced space missions. This Mission Evaluation Criterion is a decision making tool to choose among space missions; it is useful in exploratory and screening mission studies as well as in evaluating missions whose technical feasibility and cost have already been established by studies in great depth.

author

2.0 INTRODUCTION

As the progress of the national space program accelerates there is an ever growing list of technically possible future space missions to examine. What are the criteria to be used by decision makers in selecting the next manned and unmanned space missions? This study is devoted to answering this key question.

In other words, the purpose of this study is to develop a quantitative method of comparing advanced space missions for the 1970 - 1990 time period. Five advanced missions will be considered in the development of the method; and the relationships of cost, reliability, schedule, and system performance will be investigated and shown.

The scope of this undertaking is quite ambitious - involving both tangible technical analysis and intangible value judgments. The method of comparing space missions will be developed in such a way as to allow the value judgments to be made by JPL/NASA; thus the bias of individuals and the contractor will be eliminated.

In addition, a system performance index will be developed for comparing system candidates for a particular mission; and a mission evaluation criterion is developed for comparing missions.

This study is performed in support of Jet Propulsion Laboratory and in accordance with the terms and conditions of JPL Contract No. 950579.

3.0 MISSION OBJECTIVES - GENERAL

In order to develop the method five advanced space missions were considered. These missions and their appropriate premises are tabulated below:

Premises for Mission One - Jupiter Probe

Time Period for Mission Accomplishment - 1970 to 1975.

Mission Duration - Two to four years.

Unmanned

Mission Objectives - Particle and field measurements; pictures at closest approach; entry capsule to measure primary atmospheric variables, minimum atmospheric composition and establish an unmanned station.

Premises for Mission Two - Manned Lunar Base

Time Period for Mission Accomplishment - 1972 to 1980.

Mission Duration - One Year.

Crew number for resupply vehicles - 3 minimum.

Passenger number for resupply vehicles - as required.

Mission Objectives - Establish a lunar base and perform the logistics resupply mission with primary emphasis on the logistics resupply capability. The base is manned to perform lunar exploration, observation of earth, astronomy mapping and similar operations.

Premises for Mission Three - Earth Orbiting Manned Space Station

Time Period for Mission Accomplishment - 1970 to 1975.

Mission Duration - 1 Year.

Crew Number - 6 to 30 men.

Mission Objectives - Establish low earth orbiting space station with resupply capability. The station would be used as an orbital research laboratory for experiments and observations or support for orbital assembly and launch of lunar and interplanetary vehicles. Primary emphasis will be placed on a station for assembly, check-out and launch of interplanetary vehicles.

Premises for Mission Four - Manned Mars Landing and Return

Time Period for Mission Accomplishment - 1977 to 2000.

Mission Duration - Up to two years.

Crew Number - 6 to 12.

Mission Objectives - Planetary observations, two week stay time, limited exploration and return of samples not to exceed 50 (earth) pounds.

Premises for Mission Five - Unmanned Sample Return from Venus

Time Period for Mission Accomplishment - 1970 to 1980.

Mission Duration - One to two years.

Mission Objectives - Entry and soft landing on the surface of the planet and return of a minimum of one (earth) pound of material from the planet to earth.

The reason for selecting these missions are:

1. both manned and unmanned missions are considered;
2. these missions are reasonably representative samples for the development of a method of comparing missions where the relationships of cost, reliability and system performance index are considered.

4.0 STUDY PROCEDURE

In order to show the study procedure and the relationship of various technical activities, Figure 1 is presented.

The procedure begins with Item 1, Missions Definition and is completed with Item 8, Mission Evaluation. Item 2, Operational Modes, includes trajectory selection and determination of the velocities required for various mission profiles, trip times and launch dates.

Item 3 is the synthesis of system candidates on the basis of available subsystem technology. For example, fast nuclear reactors might be considered after 1975, and similarly large launch vehicles utilizing clustered solid rockets might be considered after 1966.

Concurrent consideration of Item 4, Operations Analysis and Item 5, Vehicle Design and Analysis will lead to Item 6 the Definition of System Candidates that are feasible from the standpoint of flight performance and other technical considerations. Item 7 is the evaluation of feasible system candidates that have been defined and described in Item 6.

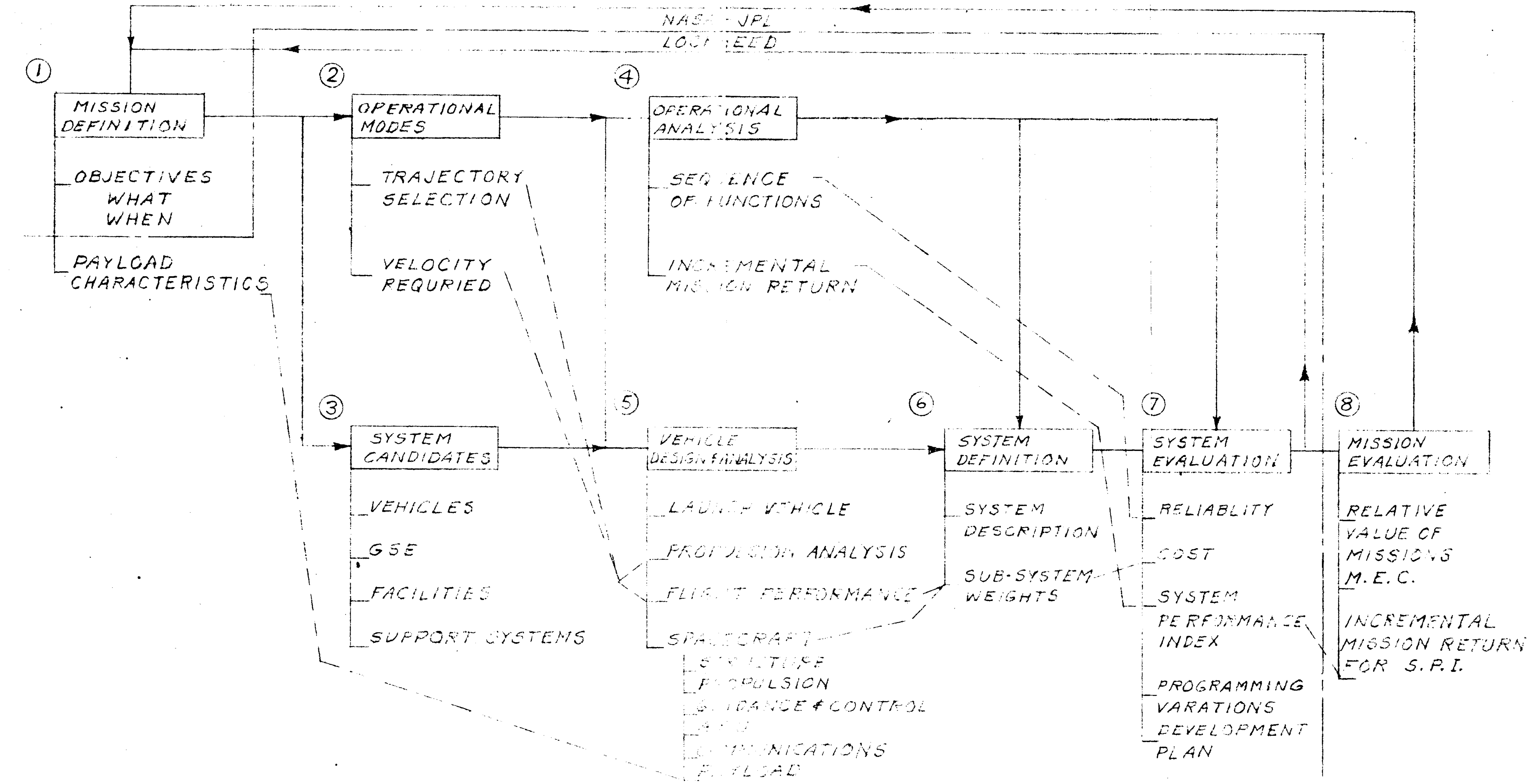
Moreover, in Item 7, the system performance index is used to select the best system candidate within any one mission. Thus, System Performance Index is a system evaluation criterion; it is defined and explained in greater detail in Section 5.6. In addition, under Item 7 the programming variations shown relate to number of launches, launch date, trip time, and type of development schedule; further details are given in Section 5.6.4.

In Item 8, Mission Evaluation, a mission evaluation criterion is considered as well as the intangible value judgments required to show the relative value of each mission. These judgments will be performed at the policy level at JPL/NASA and not by the contractor. Similarly, the incremental mission return factors for the System Performance Index represent value judgments that will be provided by JPL/NASA.

SPACECRAFT ORGANIZATION
LOCKHEED CALIFORNIA CO.

ADVANCED MISSION ANALYSIS STUDY-PROCEDURE

FIGURE 1



5.0 MISSION ONE - JUPITER PROBE

In order to illustrate the methods developed, Mission One - Jupiter Probe will be discussed, in detail now, and summary results for the other missions will be shown in Section 6.0.

5.1 Operational Modes

In general an operational mode describes the flight path, communications links, and all techniques for flight and surface operations that are required to accomplish the science and engineering objectives of a mission. In this study the selection of operational modes is limited to reasonable projections of the current technology to the time period for mission accomplishment.

The operational modes that were initially selected for consideration are summarized on page 8 and illustrated in the appendix,

Operational Mode 3a (Figure 2) was selected to demonstrate the evaluation techniques being developed in this study. This mode entails the launching of a spacecraft to penetrate transjovian space and to explore the atmosphere of the planet and the adjacent region. Data from scientific measurements made enroute to the vicinity of Jupiter will be telemetered directly to a terrestrial station. On arriving at the target planet the orbiter/entry capsule is released for planet capture; subsequently the measurements are made by instruments aboard both the main spacecraft and the capsule. Data collected by the capsule is telemetered to the main spacecraft from which it is then transmitted earthward. Capsule-to-spacecraft and spacecraft-to-earth data transmission will not be possible at all times; therefore, data storage capability must be provided on board both vehicles.

Estimated velocity requirements for three different interplanetary trip times for the Jupiter Probe mission are shown in Table I. Evaluations of the mission were made for all three trip times shown. The velocity requirements were estimated by means of References 4, 6 and a graphical method developed in support of this study. Details of the graphical technique are presented in the appendix of this report.

5.1 Operational Modes

1. Flyby - Spacecraft is launched into earth orbit, from which it is injected on an interplanetary trajectory which penetrates the near vicinity of Jupiter. (Figures 1 and 7).

2. Main Spacecraft in Capture Orbit - Spacecraft is launched into earth orbit, from which it is injected on a trans-Jovian trajectory. Retrograde velocity adjustments applied near the perijove of the trajectory establishes the spacecraft in an elliptical orbit around the planet. (Figures 2 and 7).

3. Flyby with Orbiter Capsule Release - Spacecraft is launched into earth orbit and injected on flyby trajectory. Near the perijove of the hyperbolic flyby trajectory an instrumented capsule is released from the main spacecraft. Retrograde velocity adjustments enable the capsule to transfer to an elliptical capture orbit. Main spacecraft later provides a communications link between the orbiting capsule and terrestrial stations. (Figures 3 and 7).

   3a. Flyby with Orbiter/Reentry Capsule Release - Same as (3) above except that the altitude of the orbiting capsule is diminished periodically by transfer to smaller orbits. The capsule spirals incrementally toward the planet, eventually entering the jovian atmosphere. (Figures 3 and 7).

4. Flyby with Orbiter Capsule Release and with Auxiliary Communications Spacecraft - Same as (3) above except that a communications relay spacecraft is launched on an interplanetary trajectory to provide an additional communication link between the earth-returning main spacecraft and terrestrial monitoring stations. (Figures 4 and 7).

5. Flyby with Orbiter Capsule Release and with Earth Orbiting Communications Relay - Same as (3) above except that an earth orbiting space station is used as a communication link between the earth-returning main spacecraft and terrestrial monitoring stations. (Figures 5 and 7).

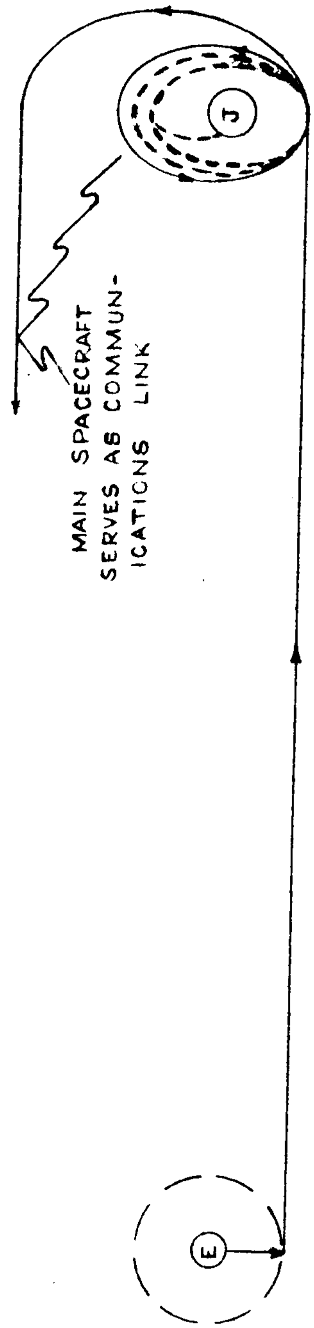
6. Earth Orbital Assembly/Flyby with Orbiter Capsule Release - Same as (3) above except that earth orbit assembly techniques are employed to enable buildup of large chemical propellant spacecraft. (Figures 6 and 7).

TABLE 1

TRAJECTORY DATA
JUPITER PROBE

LAUNCH DATE - FIRST FLIGHT	2-3-70		
Total Trip Time (days)	997	730	548
Velocity Increments - Transfer, Capture, Etc. (ft/sec x 10^{-3}) Earth Orbit (100 N.M.) Departure	20.75	21.35	23.35
Retro For Jovian Capture (e = 0.8, 122,000 NM Perijove)	11.8	13.4	15.5
Velocity Increments - Guidance Maneuvers (ft/sec x10^{-3})			
Injection	0.5	0.5	0.5
Midcourse	0.5	0.5	0.5
First Approach	1.0	1.0	1.0
Final Approach	1.0	1.0	1.0

FLYBY WITH ORBITER CAPSULE RELEASE



JUPITER PROBE
OPERATIONAL MODE NO. 3 & 3a

FIGURE 2

5.2 System Candidates

For each operational mode described previously, one or more system candidates were specified for preliminary consideration. The various subsystems considered in these candidates are shown in Table 2. The system candidate considered for further detailed study was, S-5, as shown by the combination of subsystems outlined in Table 2 by heavy rectangles.

TABLE 2

SYSTEM CANDIDATES - JUPITER PROBE

LAUNCH VEHICLE	MAIN SPACECRAFT			CAPSULE		
	PROPULSION	APU	G/C	PROPULSION	APU	G/C
Saturn 5	Cryogenic Solid	Solar Cells	Radio Command	Cryogenic	Battery	
Saturn 1B Plus Centaur	Storable*	Nuclear	Astro Inertial	Storable	Fuel Cells	Astro-Inertial
Saturn 5 Less S-IV B	Nuclear Heat Exch. Nuclear Electric					

* For Mid-Course Corrections Only; D.S.I.F. - Throughout.

5.3 Operations Analysis

The evaluation of selected operational mode/system candidate combinations by which a mission is implemented entails the assignment of value, hereafter called incremental mission return, to the functional objectives of the mission. This was done by first identifying all possible objectives of the mission which, if successfully accomplished, provide incremental mission return in the sense that a contribution is made to the nation's space flight program. These mission objectives are not limited to those which can be accomplished by specific operational mode/system candidate combinations; the list may include objectives which cannot be accomplished by any of the combinations.

Having identified the sources of value within a mission, each is assigned an incremental mission return factor (Δm.r.) based on the prorationing of points according to the value of each mission objective. In this study a total of one-hundred points were distributed among the objectives of each mission. Figure 3 shows a tabulation of objectives and assigned incremental mission returns for the Jupiter Probe mission when carried out by operational mode 3a. This particular operational mode enables the accomplishment of all possible mission objectives; hence, the total of the assigned incremental mission returns is one-hundred points.

Appropriate analyses were also conducted to establish a sequence of functional objectives for the operational mode/system candidate combination selected for evaluation. A functional sequence is essentially a list of engineering and science events which must be accomplished to fulfill the specific mission objectives. The events are listed in the order in which they occur in a normal mission. The successful completion of a single event in the sequence is not necessarily contingent on the successful completion of all prior events although this is frequently the case. Figure 4 in Section 5.3 shows a functional sequence for the Jupiter Probe mission when carried out by operational mode 3a.

16

INCREMENTAL MISSION RETURN FACTORS

MISSION: JUPITER PROBE
OPERATIONAL MODE: 3a

FIGURE 3

FUNCTIONAL OBJECTIVE	PHASE I NEAR EARTH REGION - TO 10^6N.Mi. ALT.		PHASE II NEAR EARTH REGION TO ASTEROID BELT		PHASE III ASTEROID BELT		PHASE IV ASTEROID BELT TO NEAR JUPITER REGION		PHASE V NEAR JUPITER REGION 10^6N. Mi. TO ORBIT		PHASE VI JUPITER ATMOSPHERE		TOTAL	
	FLIGHT	SCIENCE	FLIGHT	SCIENCE	FLIGHT	SCIENCE	FLIGHT	SCIENCE	FLIGHT	SCIENCE	FLIGHT	SCIENCE	FLIGHT	SCIENCE
LAUNCH FLIGHT FUNCTIONS														
Launch Into Earth Orbit	1												1	
Interplanetary Injection	4												4	
SPACECRAFT FLIGHT FUNCTIONS														
Injection Guidance Maneuvers	4												4	
Midcourse Guidance Maneuvers					5								5	
Approach Guidance Maneuvers							6		10				16	
CAPSULE FLIGHT FUNCTIONS														
Jupiter Capture Maneuver									8				8	
Deorbit Maneuver											12		12	
SPACECRAFT SCIENCE FUNCTIONS														
Spectrometer Measurements Of Earth		1												1
Magnetic Field Measurements		-		1		1		1		-				3
Proton And Electron Flux Measurements		-		1		1		1		-				3
Meteoroid Measurements						1				1				2
IR Spectrometer Measurements Of Jupiter		1		1		1		2		4				9
U.V. Spectrometer Measurements Of Jupiter		-		-		1		1		2				4
Visible Spectrometer Measurements Of Jupiter		-		-		-		1		1				2
Spectrometer Measurements Of Jupiter Nightside										3				3
Television Pictures Of Jupiter										4				4
Television Pictures Of Jovian Moons & Asteroids										2				2
Microwave Radiometer Measurements										2				2
IR Radiometer Measurements										2				2
Radio Noise Measurements Of Jupiter										1				1
CAPSULE SCIENCE FUNCTIONS														
Reentry Phenomena Measurements												6		6
IR Radiometer Measurements - Jovian Orbit										1				1
Meteoroid Measurements - Jovian Orbit										1				1
Proton And Electron Flux - Jovian Orbit										2				2
Magnetic Field Measurements - Jovian Orbit.										2				2
													50	50

MISSION: NEPTUNE PROBE
OPERATIONAL MODE: 3a

FUNCTIONAL SEQUENCE AND PROBABLE MISSION RETURN

NINE - SPACECRAFT

TIME (DAYS)	FUNCTIONAL OBJECTIVE	Δ m.r.	R_{EC}	Δ m.r. R_{EC}
0	Launch Into Earth Orbit	1	.999	.999
0.5	Interplanetary Injection	4	.999	3.996
1.5	Injection Guidance Maneuver	4	.999	3.996
3	Phase I Science Functions. Duration - 7 Days	2	.999	1.998
10	Phase II Science Functions. Duration - 78 Days	3	.999	2.997
88	Midcourse Guidance Maneuver	5	.998	4.990
89	Phase III Science Functions Duration - 606 Days	5	.334	1.670
694	Conduct First Approach Guidance Maneuver	6	.352	2.112
695	Phase IV Science Functions Duration - 290 Days	6	.092	.552
900	Conduct Final Approach Guidance Maneuver	10	.155	1.550
984	Phase V Science Functions on Main Spacecraft. Duration = 13 days	22	.077	1.695
985	Separate Capsule From Spacecraft	-	-	-
985	Capsule Retrograde For Planetary Capture	8	.012	.096
985	Phase V Science Functions On Capsule. Duration - 15 Days	6	.073	.438
1000	Capsule Retrograde for Deorbit Maneuver	12	.085	1.020
1001	Atmospheric Entry Of Capsule. Phase VI Science Functions	6	.083	.498
		100		28.607

5.4 Vehicle Design & Flight Performance Analysis

In evaluating operational mode 3a and the selected system candidate, S-5, for the Jupiter Probe mission the spacecraft and capsule payloads, were considered to be invariant with trip time. Under this constraint the major considerations were the variation in retro velocity required for target planet capture and the variation in earth-orbit departure velocity. Figure 5 shows the relationship between trip-time and these two requirements while Figure 6 shows the effect of their variations on capsule weight and main spacecraft weight at departure from earth orbit.

In Figure 7 the spacecraft weight is again shown, along with the launch vehicle, Saturn 5, capability. This figure shows that for trip times of 997 days and 730 days the performance of the Saturn 5 launch vehicle is satisfactory for launch and earth-departure. The weight of a spacecraft designed for a 548 day trip however, exceeds the capability of the Saturn 5.

Susbystem investigations were carried out during this portion of the study primarily to obtain weight data and assess technical feasibility. The weight data for the best operational mode/system candidate combination for Jupiter Probe is tabulated in Section 5.5, System Definition.

In addition, a typical in-board profile made during the design investigations is shown on page 20 for the nuclear electric powered Jupiter Probe.

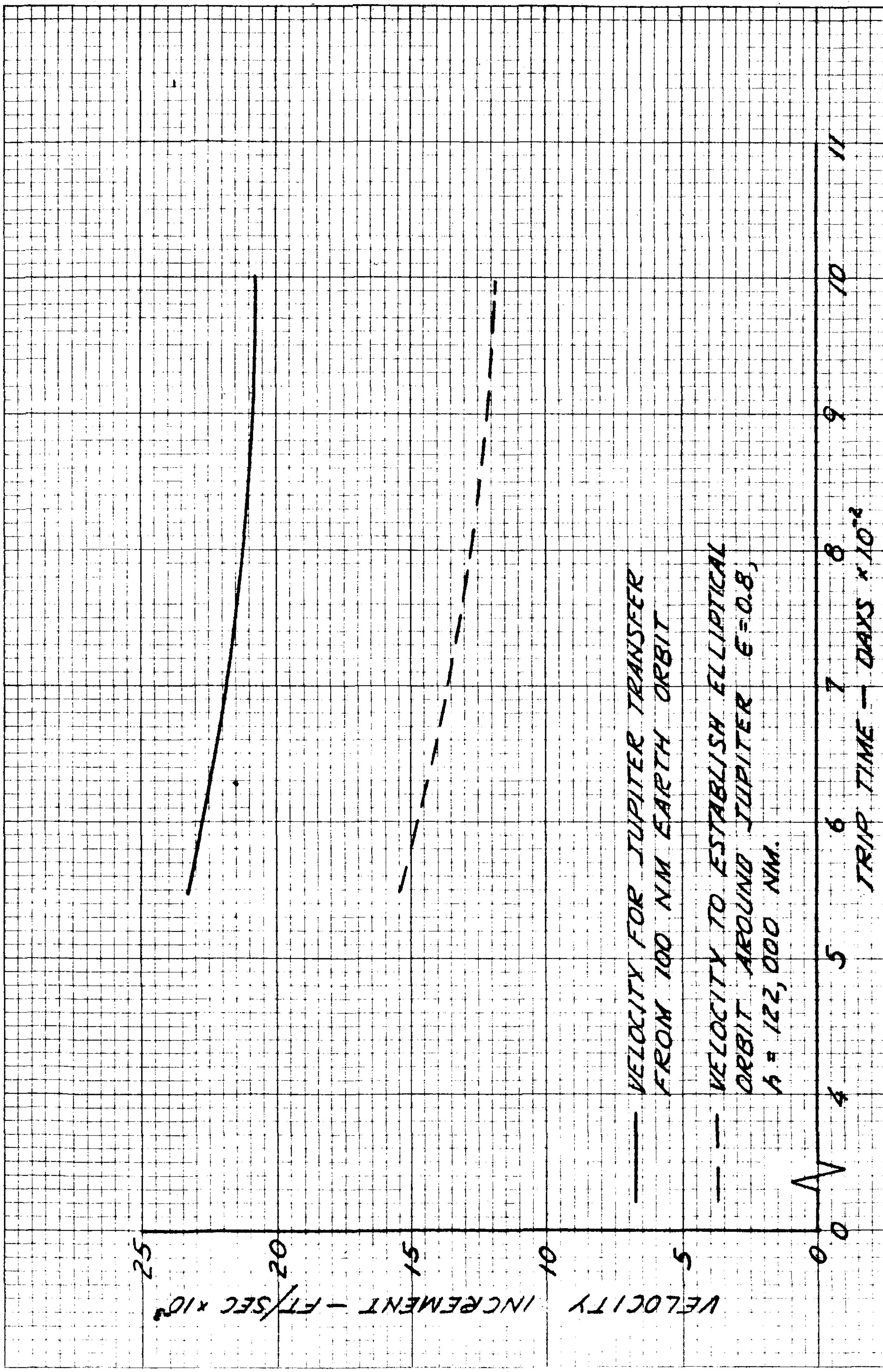


FIGURE 5 – CHARACTERISTIC VELOCITY
EARTH TO JUPITER TRANSFER

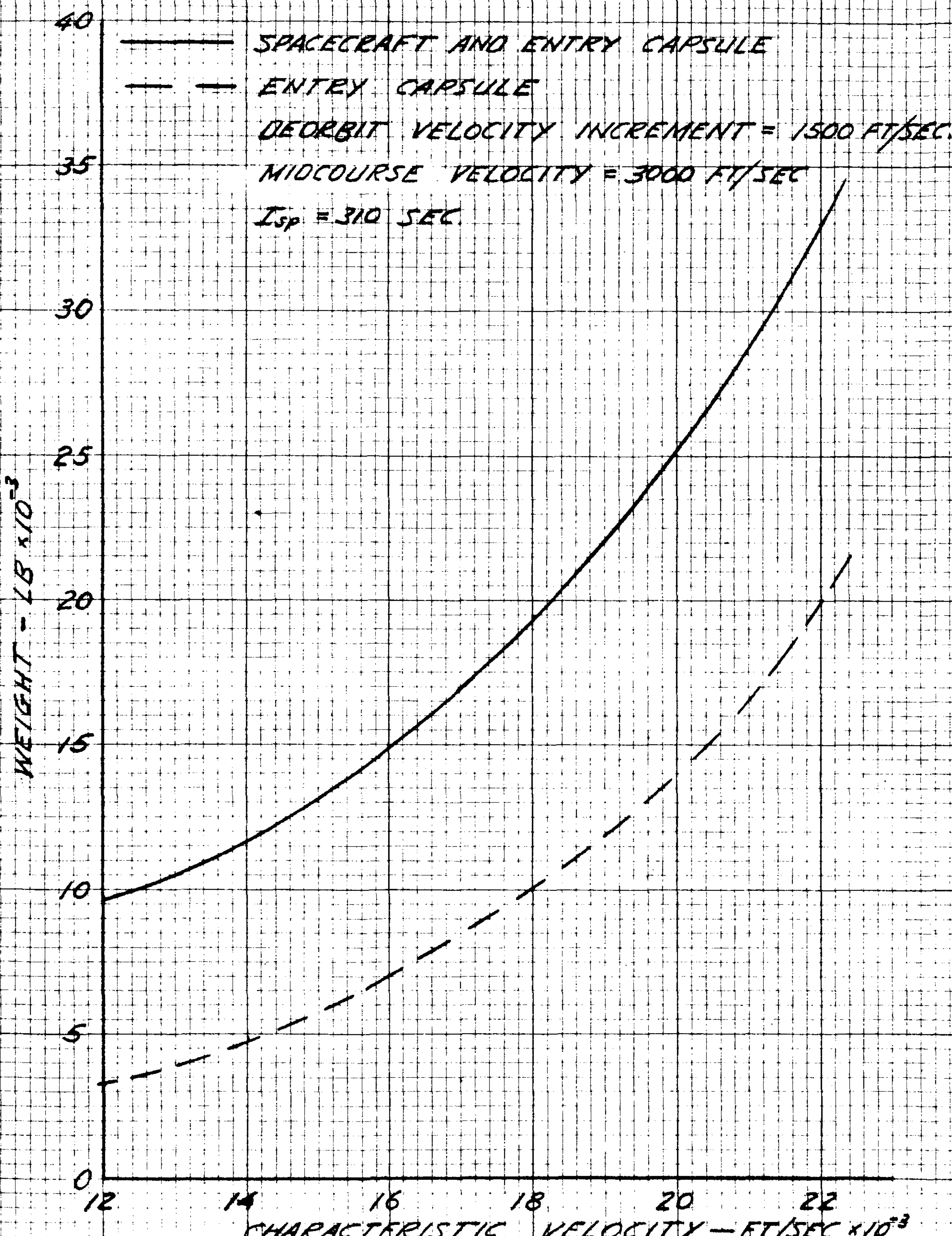
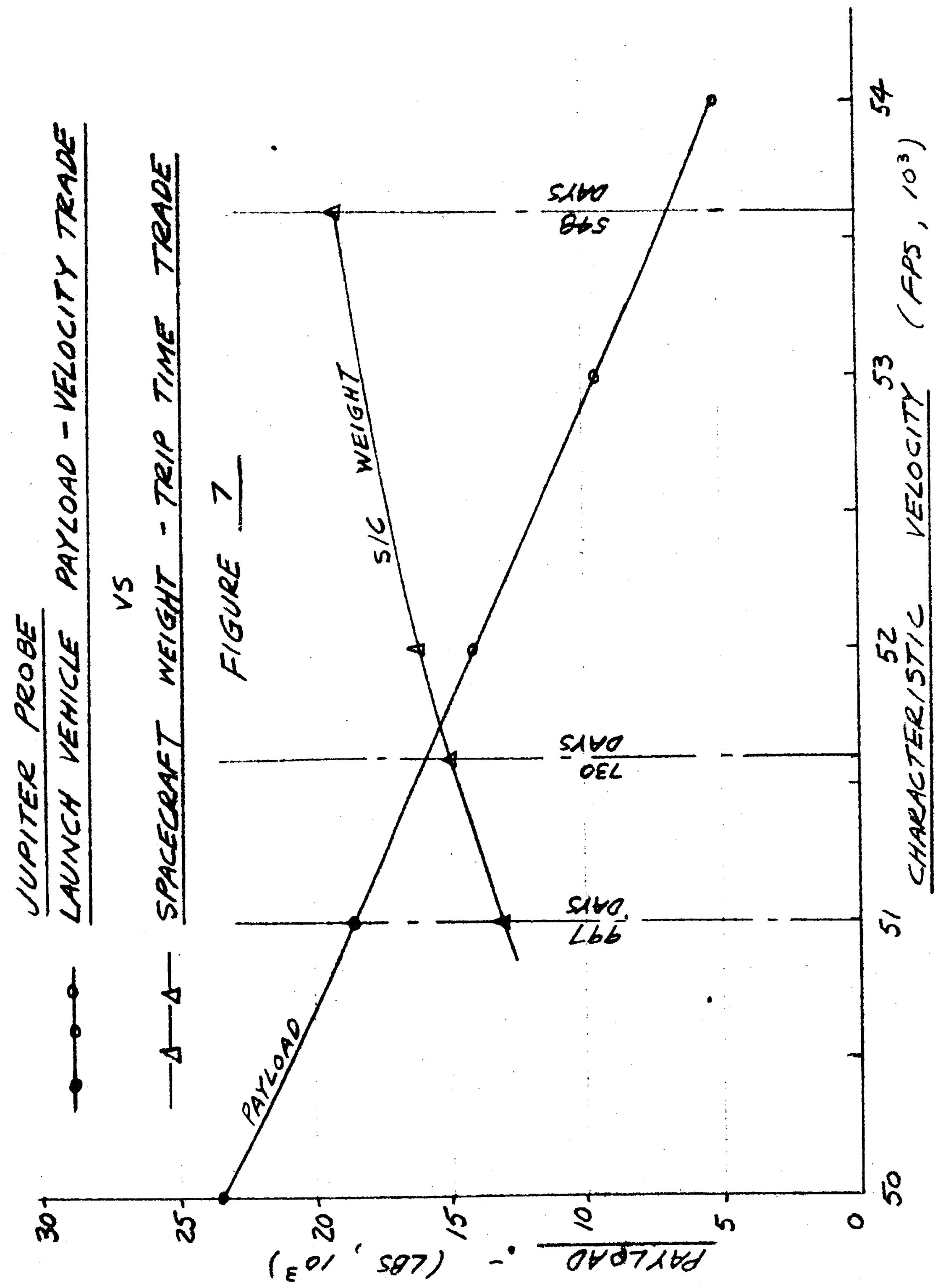
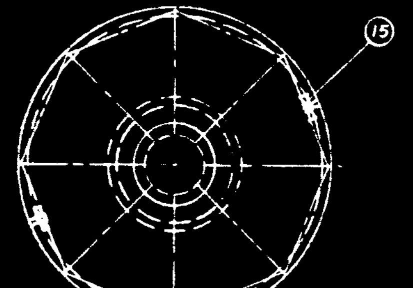


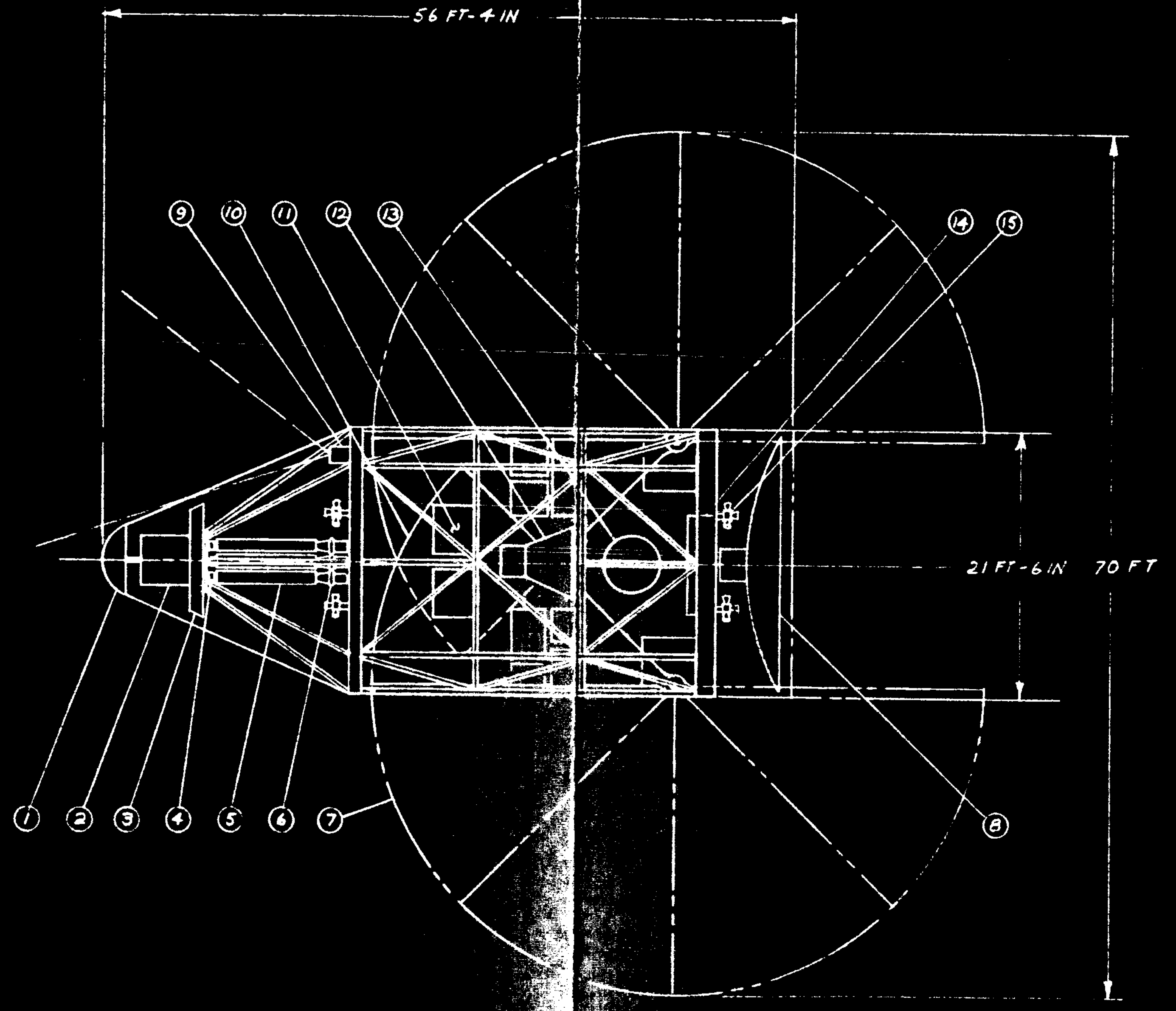
FIGURE 6 - SPACECRAFT AND ENTRY CAPSULE WEIGHT — JUPITER PROBE

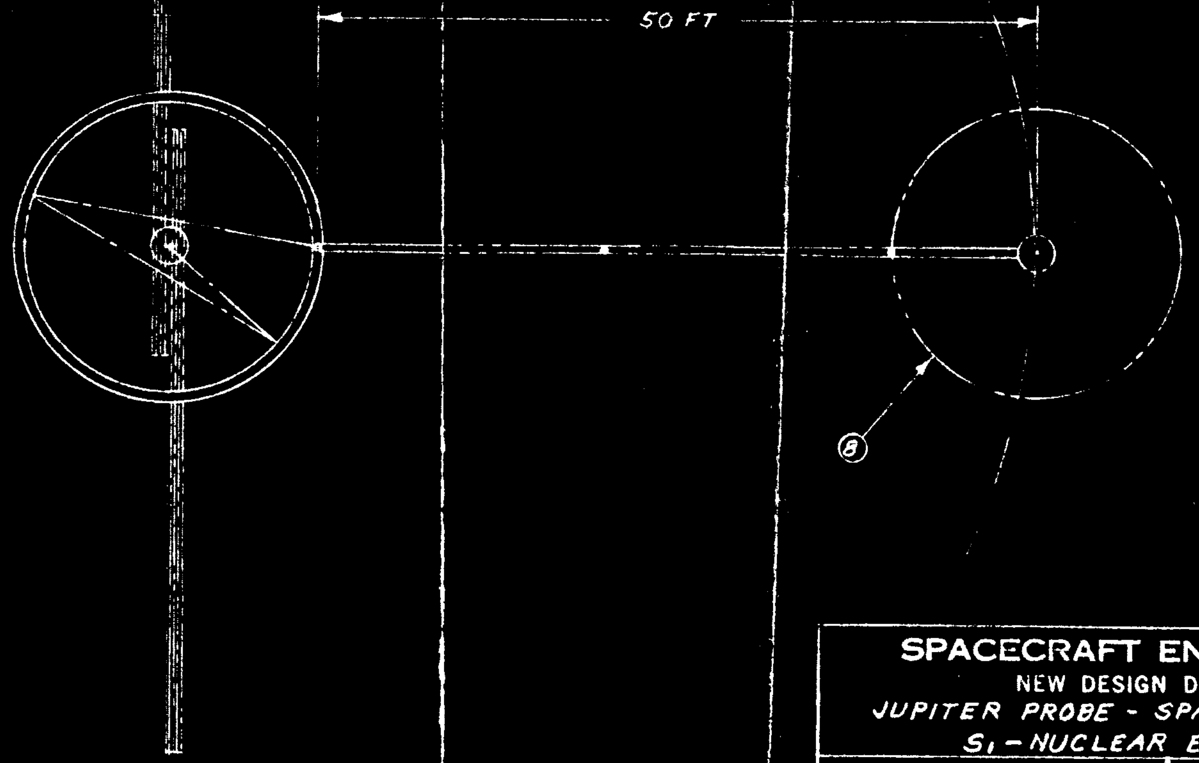
PREPARED BY	DATE	LOCKHEED-CALIFORNIA COMPANY A DIVISION OF LOCKHEED AIRCRAFT CORPORATION	PAGE 19
CHECKED		TITLE	MODEL
APPROVED			REPORT NO. LR 17358



1 BUFFER
2 REACTOR
3 SHIELD
4 PUMPS (4)
5 BOILERS (4)
6 TURBO GENERATORS (4)
7 RADIATORS
8 ANTENNA (20 FT. DIA.)
9 CAMERA AND MAIN S/C SC. PYLD
10 RADIATORS, RETRACTED
11 COMMUNICATIONS, ETC.
12 ENTRY AND/OR ORBITING CAPSULE
13 CESIUM TANK
14 ION ENGINE
15 PITCH, YAW, AND ROLL JETS







WEIGHTS - POUNDS

PROPULSION		20,800
REACTOR	800	
SHIELD	1 000	
POWER GENERATORS	1 420	
BOILERS AND PUMPS	780	
CESIUM TANK AND SUPPORT	150	
CESIUM	5 000	
RADIATORS	5 600	
CONDENSERS	400	
POWER CONVERSION	1 000	
ION ENGINE	4 000	
LIQUID METAL	650	
GUIDANCE AND CONTROL		
COMMUNICATIONS		2500
APU		
SCIENTIFIC PAY LOAD		
STRUCTURE AND SHROUD		3500
ENTRY CAPSULE		2200
PROPULSION	400	
PROPELLANTS		
SCIENTIFIC PAYLOAD	300	
STRUCTURE	800	
GUIDANCE AND CONTROL	200	
COMMUNICATIONS	300	
POWER SUPPLY	200	
LAUNCH WEIGHT		29,000

SPACECRAFT ENGINEERING
NEW DESIGN DIVISION
JUPITER PROBE - SPACECRAFT
S_1 - NUCLEAR ELECTRIC

NAME	DATE	
ENGINEER L. STEARMAN	5-15-63	MODEL
APPROVED E. HOFFMAN	5-15-63	SCALE DRAWN 1/100
APPROVED		DWG. NO. AD 10010
APPROVED		

LOCKHEED-CALIFORNIA COMPANY
A DIVISION OF LOCKHEED AIRCRAFT CORPORATION
BURBANK, CALIFORNIA

5.5 System Definition

The system candidate selected for detailed evaluation in the Jupiter Probe mission is defined in this section.

Table 3 lists the major characteristics of the Jupiter Probe system candidate. This description together with the spacecraft weight summary in Table 4 represents the depth to which the system was defined for purposes of the evaluation. The results of analyses conducted in support of this definition appear in other sections of this report and in the appendix.

A Saturn 5 vehicle is used to launch the spacecraft into interplanetary trajectory via an earth parking orbit. Earth orbit is achieved after only a portion of the S IV B propellants are spent. Earth departure velocity is provided by the unspent propellants of the S IV B, thus requiring restart of that stage. The spacecraft provides only the propulsion required for mid-course correction guidance maneuvers during flight.

TABLE 3

JUPITER PROBE SYSTEM CANDIDATE

MAIN SPACECRAFT

Payload - Scientific Equipment
Guidance Propulsion - N_2O_4/Aerozine 50
Guidance - Astro - Inertial
Attitude Control - Reaction jets and inertia wheels
APU - Nuclear, 6 Kw
Communications - 2300 megacycles, 200 bits/sec.

CAPSULE

Payload - Scientific Equipment
Planet Capture Propulsion - N_2O_4/Aerozine 50
Deorbit Propulsion - N_2O_4/Aerozine 50
Power Supply - Battery
Guidance - Astro-Inertial
Attitude Control - Reaction jets and inertia wheels
Communications

LAUNCH VEHICLE - SATURN 5

First Stage - S-IC
Second Stage - S-II
Third Stage - S-IV-B w/Restart

G.O.S.S. - Deep Space Instrumentation Facility

G.S.E - Saturn 5 and Spacecraft

LAUNCH FACILITY - Atlantic Missile Range.

TABLE 4

SPACECRAFT WEIGHT SUMMARY

Main Spacecraft Scientific Equipment			200 lbs
Spectrometers		70	
Magnetometers		6.5	
Radiation Detector		18.5	
Radiometers		25	
Meteoroid Detector		5	
Television Camera		25	
Radio Noise Detector		5	
Controls, Scanners, Shields, etc.		45	
Environmental Control			620
Reentry Capsule			4820
Scientific Equipment		65	
Radiometers	25		
Meteoroid Detector	5		
Radiation Detector	18.5		
Magnetometers	6.5		
Controls, etc.	10.		
Communication System		60	
Environmental Control		35	
Guidance & Navigation		40	
Control		20	
Propulsion (Isp = 310)		3330	
Power Supply		110	
Structure and Reentry Shield		220	
Propulsion System (Isp = 310)			3700
Engine		80	
Propellant Tanks		160	
Pressurization System		190	
Shielding and Insulation		90	
Structure		30	
Propellants		3150	
Control			300
Accessory Power Supply			800
Communication System			480
Guidance And Navigation			320
Structure			700
TOTAL			11000 lbs.

5.6 System Evaluation

5.6.1 Reliability

The evaluation of a system candidate requires a quantitative determination of the candidate's capability to accomplish specified mission objectives. This is done on the basis of reliability analyses.

The first step in an evaluation procedure of this type is to identify the function or chain of sequential independent functions required to insure successful completion of mission objectives. Each objective to which incremental mission return factors (m.r.) have been assigned must be considered. The assignment of m.r.'s to mission objectives is covered in Section 5.3 of this report. Each of these functions is contingent on the proper operation of a set of subsystems. The reliability of the subsystems form the basis on which the probability of successfully accomplishing mission objectives is determined. Table 5 identifies the subsystems on which accomplishment of the various objectives of the Jupiter Probe mission depends.

The probability of successfully accomplishing mission objectives was first determined for a single mission attempt; that is, for a single launch program. The probabilities of accomplishing the various mission objectives in a single launch program were determined by:

$$R_i = \prod_{j=1}^{N_1} (R_S)_j \prod_{K=1}^{N_2} e^{-\lambda_K t_K}$$

where:

R_i = Probability of successfully completing the i^{th} mission objective.

$(R_S)_j$ = Reliability of the j^{th} "one-shot" or single-use subsystem required for accomplishing the i^{th} objective

λ_K = Expected failure rate of the K^{th} continuous - use subsystem required for accomplishing the i^{th} objective.

t_K = Total elapsed operating time required of the K^{th} continuous-use subsystem for accomplishing the i^{th} objective.

After determining the probability of successfully accomplishing each mission objective for a single launch program, the probability of successfully completing the objectives once in a multiple launch program can be determined by:

$$(R_1)_n = 1 - (1 - R_1)^n$$

where:

n = Number of launches in the program.

Table 6 presents the probabilities of accomplishing the Jupiter Probe mission objectives at least once for programs involving 1, 3, 6 and 9 launches as determined by the above method. In this summary table, the reliabilities of the individual science functions performed during a phase are not tabulated. The reliabilities shown in the table are effective reliabilities, computed by weighting the individual function reliabilities by the incremental mission return from each function.

The reliability data used in the Jupiter Probe evaluation is presented in Tables 7, 8, and 9. Figure 8 shows the launch vehicle reliability growth that can be expected during the Jupiter Probe program. No reliability growth was assumed in the determination of spacecraft function reliabilities.

Figure 9 shows a typical reliability estimate for a Jupiter Probe spacecraft subsystem and the equivalent subsystem for the Mariner spacecraft. It can be seen that an order of magnitude improvement in failure rate was assumed over that estimated for Mariner. The same magnitude of improvement was assumed over present capability for all Jupiter Probe subsystems.

TABLE 5

JUPITER PROBE

REQUIRED RELIABILITY CHAINS

MISSION OBJECTIVES

SUBSYSTEMS	Launch To Earth Orbit	Interplanetary Injection	Injection Maneuver	Phase I Science	Phase II Science	Midcourse Maneuver	Phase III Science	First Approach Maneuver	Phase IV Science	Final Approach Maneuver	Phase V Science	CAPSULE Release	CAPSULE Capture	CAPSULE De-orbit	CAPSULE Atmospheric Entry	CAPSULE Science
Launch Vehicle																
Stages (3)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Guidance	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
3rd Stage Restart		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Spacecraft Engineering																
Guidance and Navigation			X^{1}	X^{1}	X^{1}	X^{2}	X^{1}	X^{3}	X^{1}	X^{4}	X^{4}	X^{4}	X^{4}	X^{4}	X^{4}	X^{4}
Attitude Control			X	X	X	X	X	X	X	X	X	X	X	X	X	X
Power Supply			X	X	X	X	X	X	X	X	X	X	X	X	X	X
Communication			X	X	X	X	X	X	X	X	X	X	X	X	X	X
Propulsion			X^{1}	X^{1}	X^{1}	X^{2}	X^{1}	X^{3}	X^{1}	X^{4}	X^{4}	X^{4}	X^{4}	X^{4}	X^{4}	X^{4}
Capsule Release												X	X	X	X	X
Capsule Engineering																
Guidance and Navigation													X	X	X	X
Attitude Control													X	X	X	X
Power Supply													X	X	X	X
Communication													X	X	X	X
Propulsion													X	X^{2}	X^{2}	X^{2}
Spacecraft Science																
Spectrometers				X	X		X		X		X					
Magnetometers					X		X		X							
Radiation Detector					X		X		X							
Meteoroid Detectors							X				X					
Infrared Radiometer											X					
Microwave Radiometer											X					
Radio Noise Detector											X					
Television Camera											X					
Capsule Science																
Radiometer																X
Meteoroid Detector																X
Radiation Detector																X
Magnetometers																X
Atmospheric Entry Sensors															X	X

TABLE 6

PROBABILITY OF SUCCESSFUL OBJECTIVE ACCOMPLISHMENT

FUNCTION	TIME (Days) START	ELAPSED	PLANNED LAUNCHES 1	3	6	9
Launch To Earth Orbit	0	-	.846	.996	.999	.999
Interplanetary Injection	0.5	-	.779	.989	.999	.999
Injection Guidance Maneuver	1.5	-	.736	.982	.999	.999
Phase I Science	3	7	.746	.984	.999	.999
Phase II Science	10	79	.538	.902	.994	.999
Midcourse Guidance Maneuver	88	-	.486	.854	.982	.998
Phase III Science	89	606	.044	.126	.234	.334
First Approach Maneuver	694	-	.047	.134	.251	.352
Phase IV Science	695	289	.011	.032	.062	.092
Final Approach Maneuver	900	-	.018	.055	.106	.155
Phase V Science - Spacecraft	984	17	.0089	.026	.057	.077
Capsule Separation	985	-	.017	.052	.101	.147
Capsule Planetary Capture	985	-	.0116	.004	.008	.012
Phase V - Science - Capsule	985	15	.0104	.031	.061	.073
Capsule Deorbit Maneuver	1000	-	.0096	.029	.057	.085
Capsule Atmospheric Entry	1001	-	.0094	.028	.056	.083

TABLE 7

SATURN-5 STAGE RELIABILITY

JUPITER PROBE FLIGHT NO.	CUMULATIVE LAUNCHES	STAGE RELIABILITY
1	55	.935
2	105	.942
3	180	.948
4	380	.955
5	430	.956
6	505	.957
7	555	.958
8	605	.959
9	630	.959

Assumptions For Table 7:

1. First Saturn-5 Launch - 1965
2. Fifty-five (55) Saturn-5 Launches prior to launch of first Jupiter Probe. Cumulative Saturn-5 launches at time of subsequent Jupiter Probe launches shown in Table 1.
3. Stage Reliability $(R_S) = 1 - \alpha L^{-\beta}$, according to Reference 2 ; where

   L = Cumulative launches

   α = 0.14 for Saturn-5

   β = 0.19 for Saturn-5

4. Guidance Reliability

   To Earth Orbit (R_{GO}) - 0.990

   From Earth Orbit To Injection (R_{GI}) - 0.980

5. Restart Reliability (R_R) Third Stage (S-IV B) - 0.940

TABLE 8

SPACECRAFT RELIABILITY DATA JUPITER PROBE

ENGINEERING SUBSYSTEM	SINGLE USE RELIABILITY	FAILURE RATE * $\lambda \times 10^{-6}$/HR
SPACECRAFT ENGINEERING		
Guidance & Navigation *		70
Attitude Control		27
Power Supply		10
Communication**		43
Propulsion		
Injection Guidance Maneuver	0.95	
Midcourse Guidance Maneuver	0.90	
First Approach Guidance Maneuver	0.85	
Final Approach Guidance Maneuver	0.80	
Capsule Release	0.95	
CAPSULE ENGINEERING		
Guidance & Navigation *		47
Attitude Control		9
Power Supply		6
Communication **		28
Propulsion		
Planet Capture Maneuver	0.90	
Deorbit Maneuver	0.90	

* Includes Computer, Programmer, Etc.

** Includes Encoders, Data Storage, Etc.

\+ Failure Rates are for Engineering Subsystems and Associate Thermal Controls.

TABLE 9

SPACECRAFT RELIABILITY DATA JUPITER PROBE

SCIENCE SUBSYSTEM	SINGLE USE RELIABILITY	FAILURE RATE* $\lambda \times 10^{-6}$/HR
SPACECRAFT SCIENCE		
Spectrometers		40
Magnetometers		20
Radiation Detector		15
Meteoroid Detectors		5
Infrared Radiometer		15
Microwave Radiometer		15
Radio Noise Detector		25
Television Camera		70
CAPSULE SCIENCE		
Radiometer		20
Meteoroid Detector		5
Radiation Detector		15
Magnetometers		20
Atmospheric Entry Sensor	0.98	

* Failure Rates are for Science Sensors, Associate Control Units and Thermal Control.

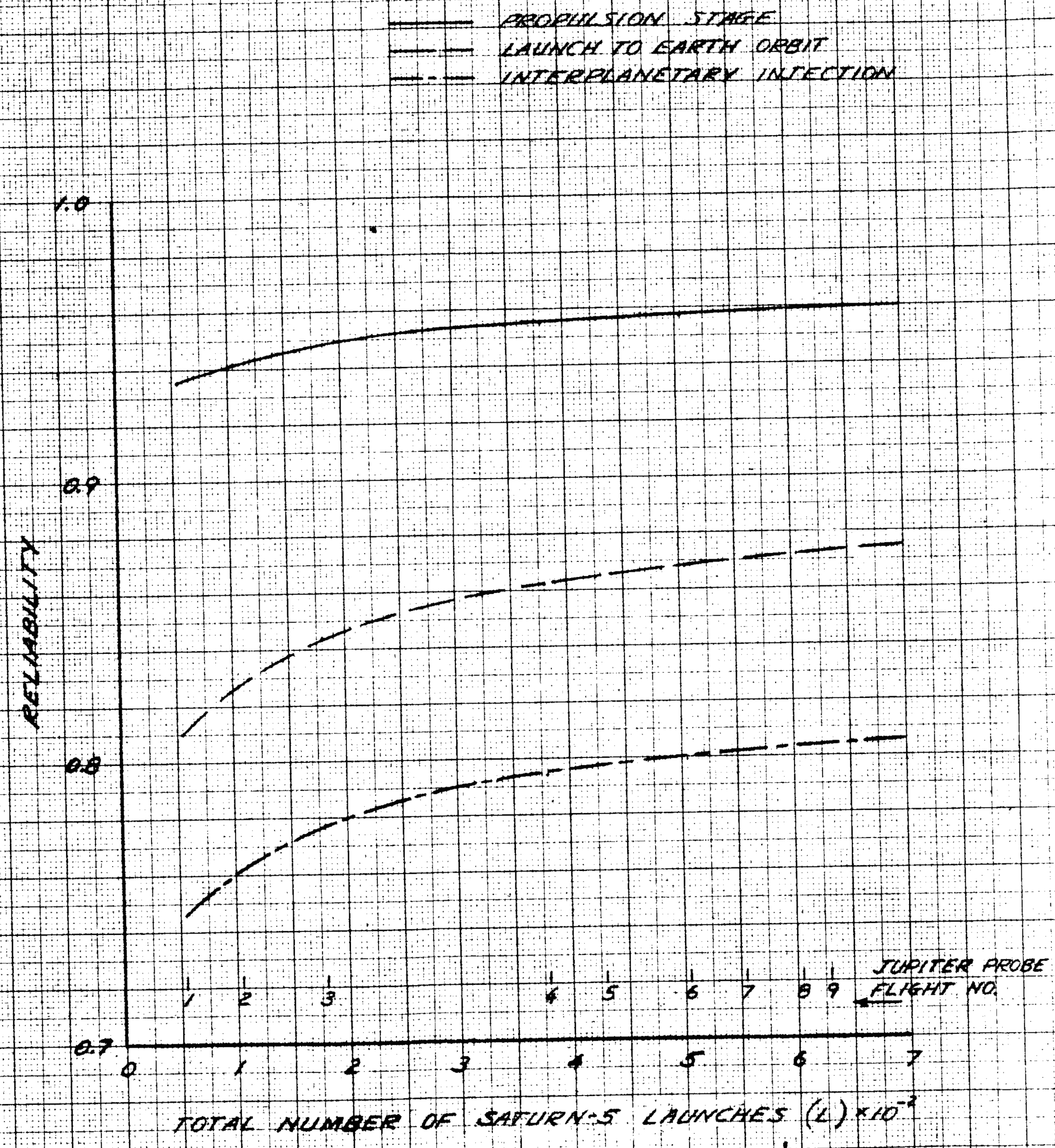


FIGURE 8-LAUNCH VEHICLE RELIABILITY FOR JUPITER PROBE MISSION

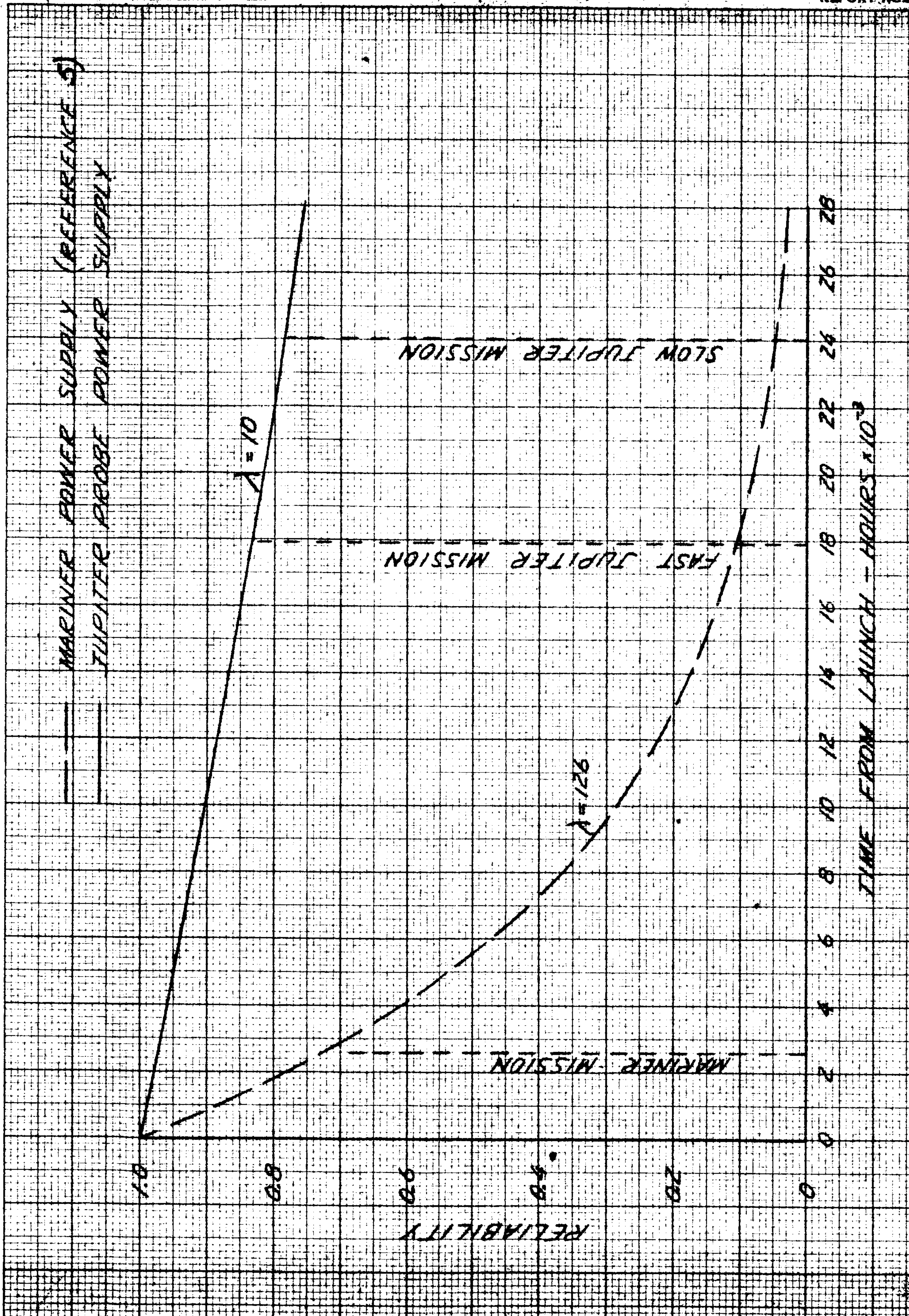


FIGURE 9 - POWER SUPPLY RELIABILITY

5.6.2 Cost

In analyzing the cost of advanced missions where subsystems are at best, not well defined, the following three-step procedure is utilized.

Step One

Analyze past program for the distribution of effort in these categories:

Engineering
Flight Hardware
GSE
Supporting R&D
Facilities
Payload Integration
Operations

In this way the ratio of Total Program Cost to Flight Hardware Cost on past programs can be determined. Tables 10 and 11 represent the results of this type of analysis on Mariner II and Mercury.

Step Two

In each mission the Flight Hardware Costs are determined using subsystem weights obtained from the Vehicle Design Analysis, Section 5.4, and subsystem parametric cost data developed. For example, for rocket engine costs are shown in Figure 10 . Other cost estimating yardsticks are tabulated in the Appendix.

Step Three

Obtain the Total Program Cost as follows:

$$\text{TOTAL PROGRAM COST} = \left[\text{FLIGHT HARDWARE COST}\right]_{\text{JUPITER PROBE}} \left[\frac{\text{TOTAL PROGRAM COST}}{\text{FLIGHT HARDWARE COST}}\right]_{\text{MARINER II}}$$

Now in the Mariner II, a past program similar in distribution of effort to the Jupiter Probe we see from page 35 that:

$$\frac{\text{TOTAL PROGRAM COST}}{\text{FLIGHT HARDWARE COST}} = \frac{100.0}{35.0} = 2.86$$

5.6.2 (Cont'd)

Therefore, for JUPITER PROBE:

$$\text{TOTAL PROGRAM COST} = \left[\text{FLIGHT HARDWARE COST}\right]_{\text{JUPITER PROBE}} \times 2.86$$

The calculation of the Jupiter Probe Costs are shown on pages 38 through 41 and summarized on page 42 .

TABLE 10

MARINER - II

ITEM	COST $,	PERCENTAGE
ENGINEERING		
Launch Vehicles		
1st Stage		
Upper Stage		
Propulsion		
Guidance & Control		
GSE		
Spacecraft	15.0	
GSE	2.0	
	17.0	23.7
FLIGHT HARDWARE		
Launch Vehicles - 2 at 8.5	17.0	
(Atlas - Agena)		
Spacecraft 2 at 4.0	8.0	
	25.0	35.0
GSE		
For LV & SC	4.0	5.6
SUPPORTING R&D	7.0	9.8
FACILITIES	4.0	5.6
PAYLOAD INTEGRATION	1.0	1.4
OPERATIONS		
Ground	2.5	
Launch & Flight	11.0	
	13.5	18.9
TOTAL	71.5	100.0

TABLE 11

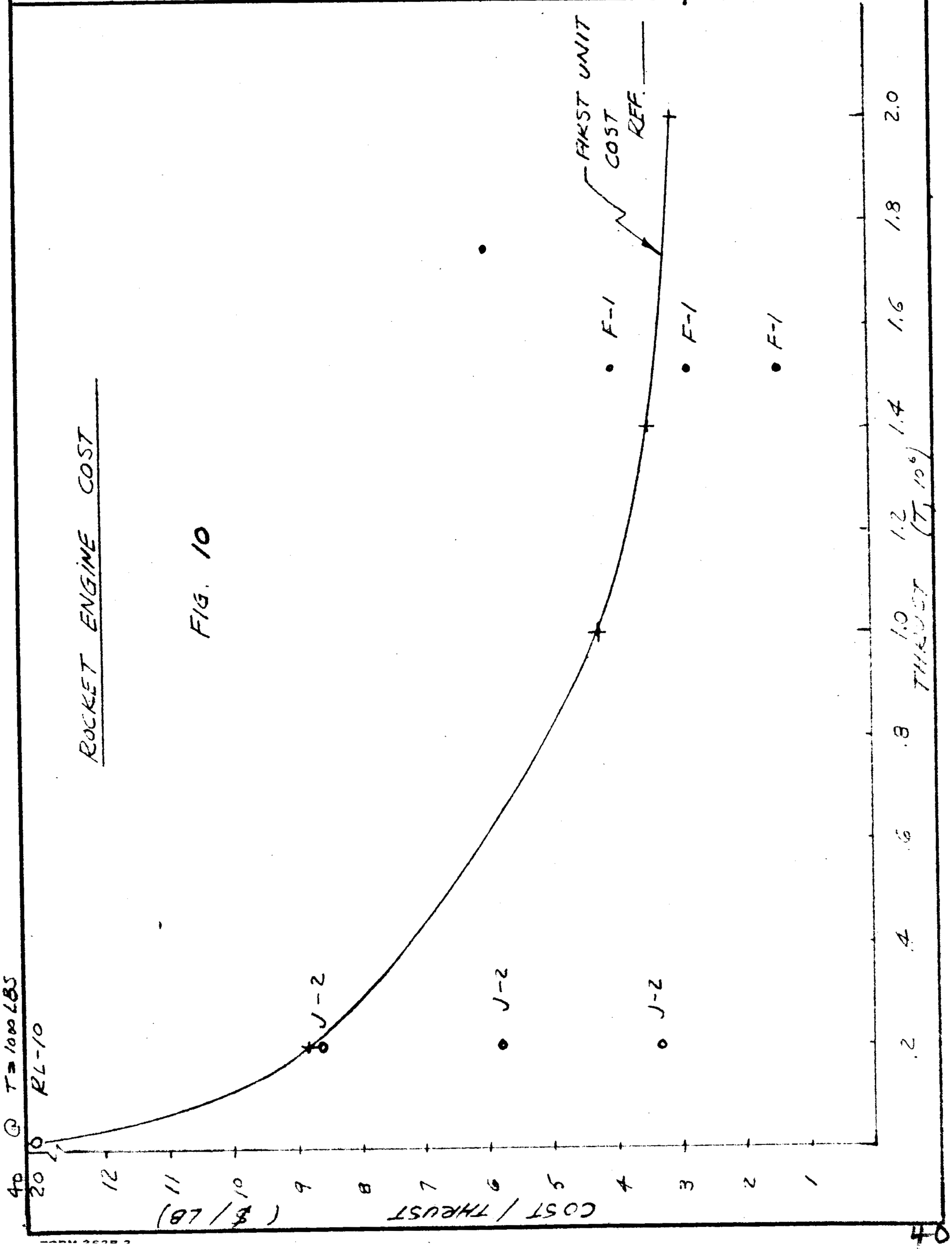
MERCURY

ITEM	COST - $M	PERCENTAGE
ENGINEERING		
LAUNCH VEHICLES		
First Stage		
Upper Stage		
Propulsion		
C&C		
GSE	11	2.1
SPACECRAFT	66	12.7
GSE	2	0.4
		15.2
FLIGHT HARDWARE		
LAUNCH VEHICLES		
Atlas 7 x $8.5	60	11.6
Spacecraft 26 x $3.6	94	18.2
		29.8
GSE - For Launch Vehicle and S/C	78	15.1
SUPPORTING R & D	75	14.5
PAYLOAD INTEGRATION	2	0.4
OPERATIONS		
GROUND	65	12.6
LAUNCH & FLIGHT	29	5.6
		55.0
	$517M	100.0%

* 26 vehicles; 7 launches
Spacecraft Weight 4753 lbs.

ROCKET ENGINE COST

FIG. 10



COST METHOD

JUPITER PROBE

For OM-3a/S-5 the following weights are used in costing the Flight Hardware:

TRIP TIME	997 DAYS	730 DAYS
S/C Total Weight	11000 lbs	13200 lbs
Less Main S/C Propellant	- 2830	- 3400
Less Capsule Propellant	- 3150	- 4450
Net Inert	5020 lbs	5350 lbs

JUPITER PROBE - COST OF MAIN SPACECRAFT & CAPSULE

TRIP TIME	997 DAYS			730 DAYS		
ITEM	LBS	$/LB	$,$10^6$	LBS	$/LB	$,$10^6$
STRUCTURE	1790	8000	14.32	2070	8000	16.55
GUIDANCE & CONTROL	835	3000	2.51	835	3000	2.51
PROPULSION	180 (T = 4000)	35.0*	.14	230 (T = 6000)	32.0*	.19
APU	850	6000	5.10	850	6000	5.10
COMMUNICATIONS	480	2000	.96	480	2000	.96
ECS	620	5000	3.10	620	5000	3.10
SC PAYLOAD	265	20000	7.30	265	20000	7.30
	5020		33.43	5350		35.71

* $/LB OF THRUST

COST METHOD

JUPITER PROBE - 997 DAYS

3 LAUNCHES

3	S-5 at 50×10^6	$= \$150.0 \times 10^6$
3	S/C at 33.43×10^6	$= \underline{100.3} \times 10^6$
		$\$250.3 \times 10^6$

TOTAL PROGRAM COST $= 250.3 \times 10^6 \times \frac{100.0}{35.0}$

LESS DEV. FOR

NUCLEAR APU

$= \$715 \times 10^6$

Δ DEV. FOR N. APU $= \underline{287} \times 10^6$

$\$1.002 \times 10^9$

6 LAUNCHES

ADD $3\ (33.43 + 50.0) \times 10^6 \times \frac{(35.0 + 18.9)}{35.0} =$

FOR 35% FLT. HDW.

& 18.9% OPERATIONS THEREFORE

ADD $3\ (83.43) \times 10^6 \times 1.54 = \$385 \times 10^6$

9 LAUNCHES

ADD $2 \times 385 \times 10^6 = \$770 \times 10^6$

COST METHOD

JUPITER PROBE - 730 DAYS

3 LAUNCHES

3 S-5 at 50.0×10^6 = $\$150.0 \times 10^6$

3 S/C at 35.71×10^6 = 107.1×10^6

$\$257.1 \times 10^6$

TOTAL PROGRAM COST = $\$257.1 \times 10^6 \times \frac{100.0}{35.0}$

LESS DEV. FOR
NUCLEAR APU

= $\$736.0 \times 10^6$

DEV. FOR N. APU $\$287.0 \times 10^6$

$\$1023.0 \times 10^6$

6 LAUNCHES

ADD $3\,(35.71 + 50.0) \times 10^6 \times 1.54$ =

$3\,(85.71) \times 10^6 \times 1.54$ = $\$396 \times 10^6$

9 LAUNCHES

ADD $2 \times 396 \times 10^6$ = $\$792 \times 10^6$

COST METHOD

JUPITER PROBE - COST SUMMARY

NO. OF LAUNCHES		TRIP TIME 997 DAYS	730 DAYS
3		$ 1.002×10^9	$ 1.023×10^9
6		1.387×10^9	1.419×10^9
9		$ 1.772×10^9	$ 1.815×10^9

5.6.3 System Performance Index

The criterion used for the evaluation of system candidates is called System Performance Index (SPI). The definition of the SPI for a single-launch program is:

$$\text{System Performance Index (SPI)} = \frac{\sum_1^n (\Delta\, m.r.)_i\, R_i}{\text{Cost}}$$

where;

$(\Delta m.r.)_i$ = Incremental mission return factor of the i^{th} mission objective

R_i = Probability of successfully accomplishing the i^{th} mission objective

Cost = Total Cost of a single - launch program.

For a multiple-launch program in which reliability growth between the first and last launches is negligible, assumes a more general form: namely;

$$(SPI)_L = \frac{\sum_1^n (\Delta m.r.)_i \left[1 - (1 - R_i)\right]^L}{(Cost)_L}$$

where:

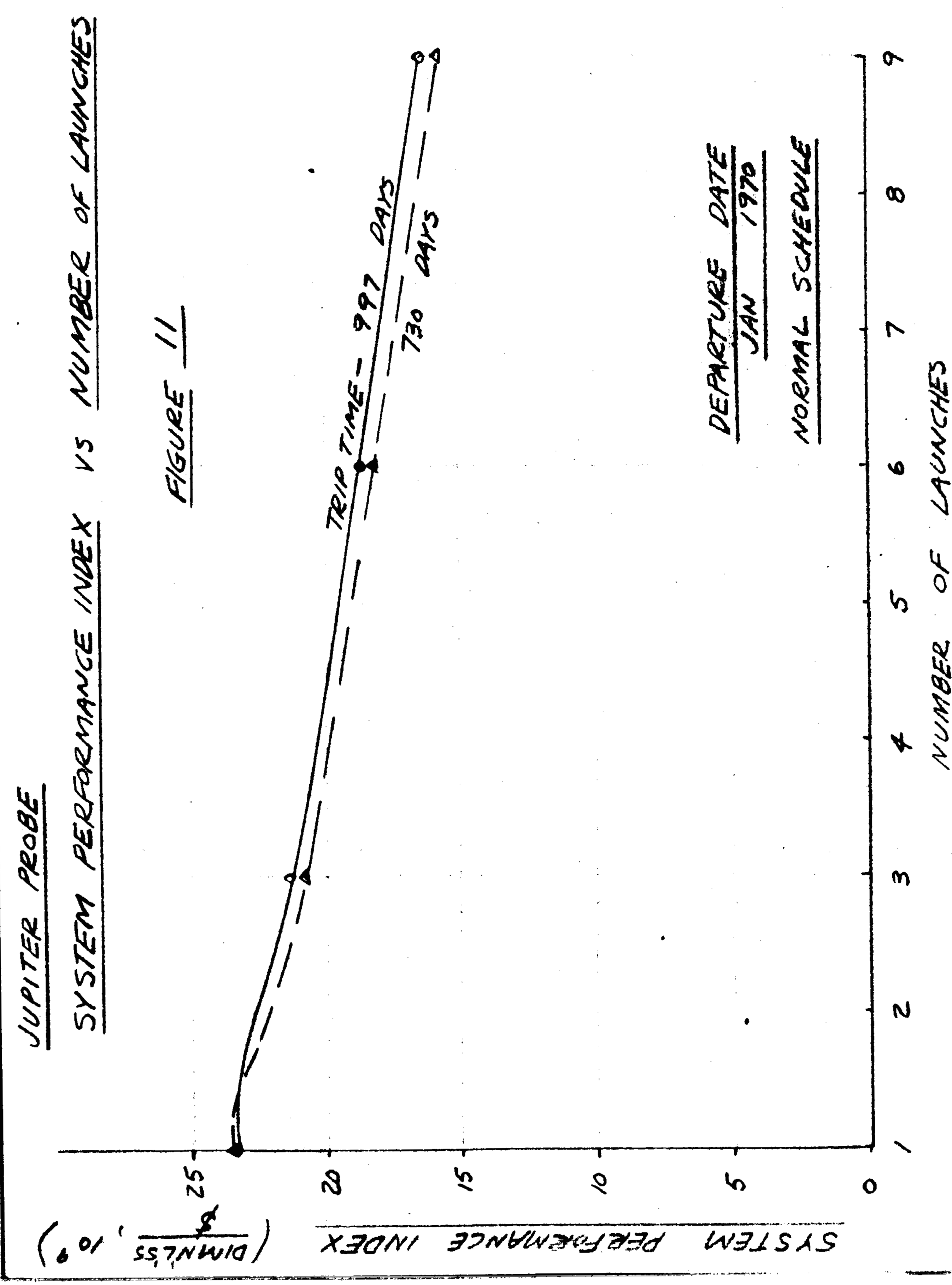
L = Number of launches

$(Cost)_L$ = Total cost of a "L" - launch program.

and where all other parameters are as defined previously.

The System Performance Indices for 3, 6 and 9 launch programs and for both 997 and 730 day trip times are plotted in Figure 11 .

PREPARED BY	DATE	LOCKHEED-CALIFORNIA COMPANY A DIVISION OF LOCKHEED AIRCRAFT CORPORATION	PAGE 44
CHECKED		TITLE	MODEL
APPROVED			REPORT NO. LR17358



FORM 362B-2

5.6.4 Programming Variations

In order to evaluate the system candidates within a mission, the following programming variations were considered:

- Number of launches
- Launch date
- Trip time
- Type of schedule

These items obviously have influence on the cost and energy required. Not so obvious is the influence of the type of schedule on cost. In general what is meant here is the influence of an accelerated, normal, or relaxed type of schedule on total program cost.

In order to illustrate the influence of the type of schedule on the Jupiter Probe - total program cost, Figure 12 is shown. These curves were obtained by calculating total program costs for a normal schedule and constructing the curves in the following way. For example the relaxed-schedule time is sufficiently long to allow incorporation of design improvements between operational launches, whereas, the accelerated-schedule time is considered the absolute minimum time assuming the application of infinite resources. Moreover, the relaxed-schedule cost is obtained by extrapolating the normal schedule costs along a line parallel to the constant cost line; whereas the accelerated schedule costs were obtained by assuming that four independent, concurrent design and development approaches were required. Perhaps, a better way to obtain the accelerated schedule costs would be to extend the curves for each number of launches asymptotically to the estimated minimum time.

PREPARED BY	DATE	LOCKHEED-CALIFORNIA COMPANY A DIVISION OF LOCKHEED AIRCRAFT CORPORATION	PAGE 46
CHECKED		TITLE	MODEL
APPROVED			REPORT NO. LR 17358

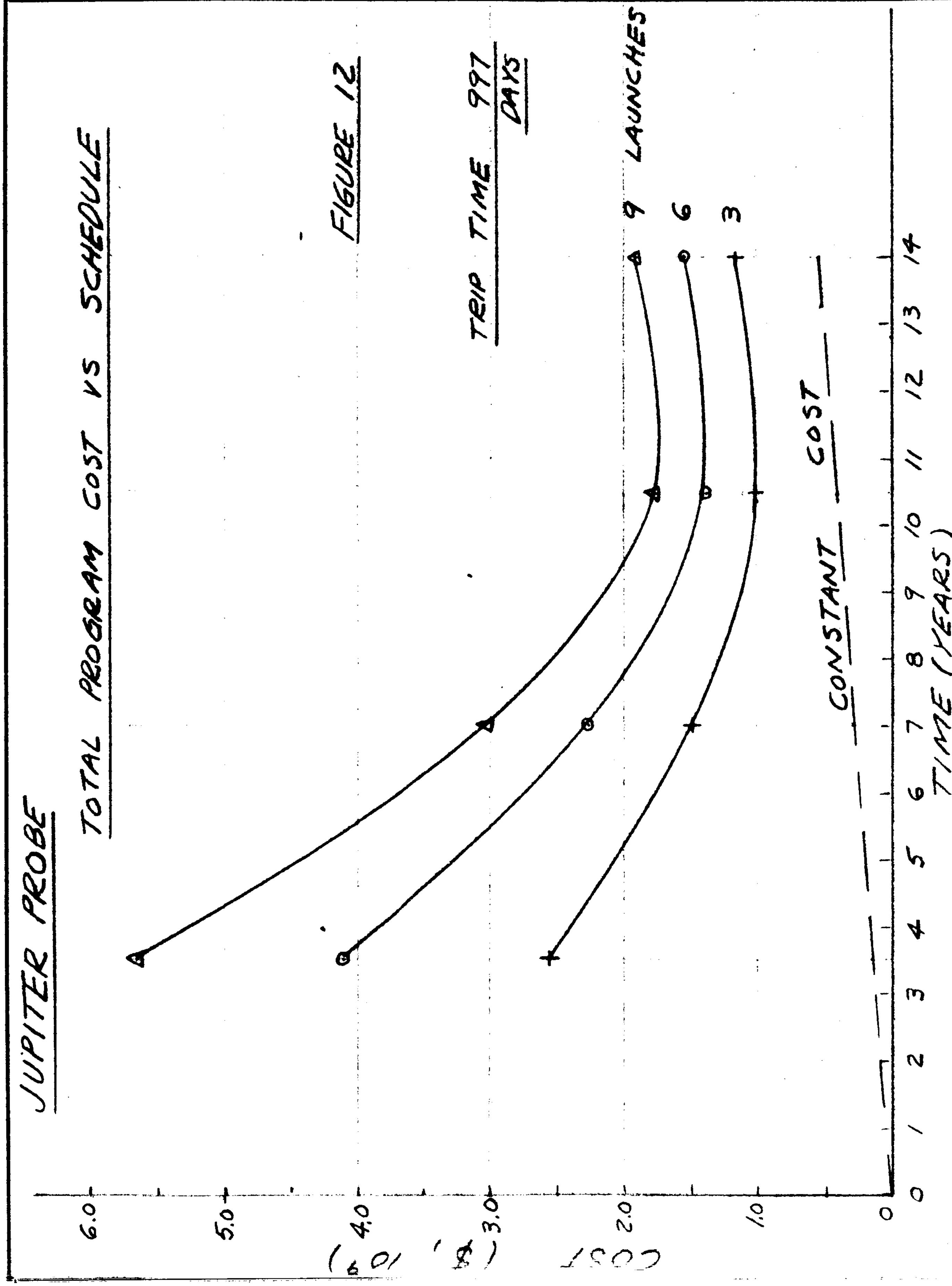


FIGURE 12

FORM 362B-2

49

5.6.5 Development Plan

A brief development plan for a nine launch Jupiter Probe mission is shown in Figure 13 . Attention is invited to the fact that although the first three launches are shown under the Development Phase, these launches are trials with full system objectives.

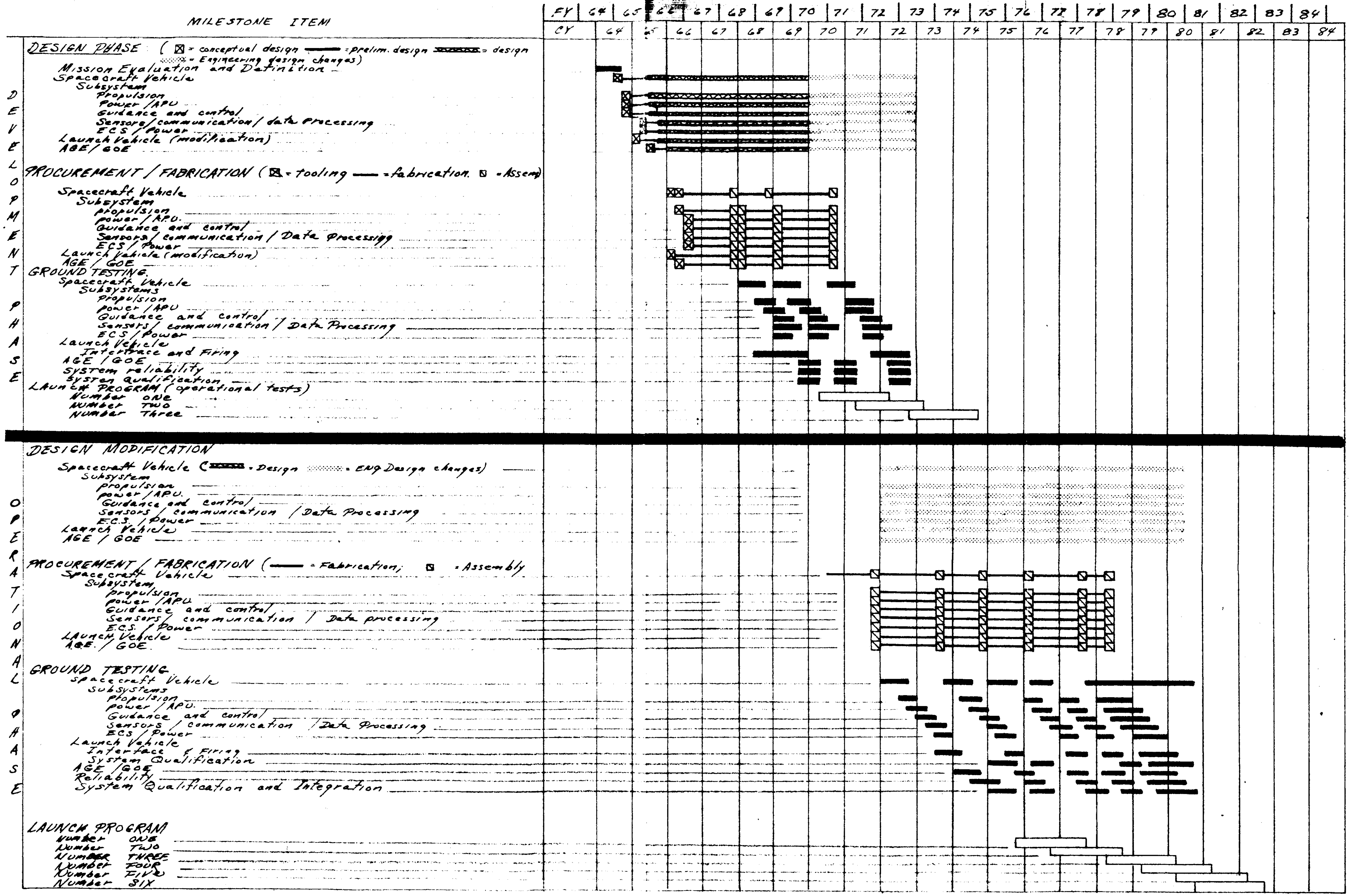
The item shown as Design Modification continues after launch number three at a reduced level and represents the effort necessary to incorporate design improvements as a result of learning during operational flights.

It is quite evident that one of the key features of a multiple launch, Jupiter Probe mission is the long program and flight durations. The program could easily cover ten to fourteen years.

JPL ADVANCE MISSI ANALYSIS
JUPITER DEVELOPMENT PLAN
CONFIGURATION

FIGURE 13

LR17358 Pg 48
DATE PREPARED: 26 AUGUST 1963



51

5.7 Mission Evaluation

The system performance index, S.P.I., described in Section 5.6.3 of this report enables the comparative evaluation of operational-mode/system-candidate combinations within one particular mission. An additional criterion is required to compare operational-mode/system-candidate combinations of one mission with those of another mission. It can be reasoned that the best operational mode/system candidate combinations from each mission can be compared if a factor of the relative value of each mission is introduced.

In this study the Mission Evaluation Criterion (M.E.C.) was used as a basis for this comparison.

The Mission Evaluation Criterion can be defined as follows:

$$\text{Mission Evaluation Criterion (MEC)} = (\text{S.P.I.})\ V_m$$

where Vm, called the Relative Mission Value, is a value judgment assigned to missions on the basis of their relative contributions to national objectives within the framework of the following considerations.

1. Science
2. Engineering
3. Political
4. Manned Space Flight
5. Military
6. Economic

5.7 Mission Evaluation

The Relative Mission Value (Vm) deals largely with the intangibles associated with the performance of missions and cannot be generated by known analytical techniques. These intangibles or imponderables may, in many instances, transcend engineering and science considerations in establishing the desirability of conducting a mission.

In this study Relative Mission Values were obtained from the results of a survey conducted at the Jet Propulsion Laboratory. A questionaire was distributed among key personnel to solicit their judgments in assigning values to the missions in the categories stated. The results of this survey, normalized to the Jupiter Probe are:

MISSION	Vm
Jupiter Probe	1.0
Manned Lunar Base	2.63
Earth Orbiting Space Station	2.40
Manned Mars Landing	3.22
Unmanned Sample Return From Venus	0.69

6.0 RESULTS FOR OTHER MISSIONS

Information pertinent to the evaluation of other missions covered in the study is summarized in this section. Additional supporting data are presented in the appendix.

6.1 System Definition

Mission Two - Manned Lunar Base

The Manned Lunar Base evaluation was made for a postulated mission in which a temporary base would be established in the vicinity of Mare Nubium. The base consists of laboratories, observatories, living quarters and associated facilities. The base would support the exploration of natural phenomena within a 200 - 300 mile radius of the Maria and would enable earth and astronomical observations.

The mission entails a one-year presupply phase and subsequently a one-year operation phase. During the first year a total of one million pounds of cargo will be transported to the lunar surface for base construction and activation. From three to nine crew members will be required on the lunar surface to perform these functions. Crew members will be rotated every 30 to 60 days in this initial phase. During the second or operation phase, fifteen crew members will be required to man the base and conduct lunar exploration; these men will be rotated on a six-month basis. The base will be resupplied with one-half million pounds of cargo during the operation phase.

The Manned Lunar Base Mission evaluation was based on the use of a modification of Operational Mode 4, as described in Monthly Progress Report No. 3. This mode, as modified, entails the transportation of all cargo to the lunar surface by means of direct unmanned flights. The lunar landing operations of these flights are supervised, i.e. controlled, by base-assembly crew members. These personnel are transported by separate flights in which the lunar-orbit rendezvous technique is utilized. Base operation personnel are transported by yet another means; namely, direct flight to the lunar surface where a portion of the landing stage is refueled for the earth return journey.

The system candidate on which the evaluation was made for the Manned Lunar Base mission is described in Tables 12 through 16 . The presupply and resupply cargo weights are summarized in Tables 12 & 13. The flight vehicles required for the

Mission Two - Manned Lunar Base (Cont'd)

entire mission are enumerated in Table 14 . Saturn 5 vehicles are used for all launches, and Apollo modules were utilized in the spacecraft whenever practicable. Descriptions of a Lunar Logistics Vehicle (LLV) and Modified Apollo Service Module, defined for this study are presented in Tables 15,16.The LLV is used in both the presupply and resupply cargo flights and the Modified Service Module is used in the transportation of base operation personnel. The latter module is equipped with throttleable engines and landing gear to permit descent to the lunar surface from orbit. The Service Module is also used to provide earth-return propulsion after being refueled on the lunar surface.

The velocity requirements for the cargo and personnel flights are presented in Table 17 . These data were used in determining flight performance for which calculations are summarized in the appendix. Also shown in the appendix are: (1) the distribution of incremental mission return factors; and (2) a functional sequence for the mission.

TABLE 12

PRESUPPLY WEIGHT SUMMARY/MANNED LUNAR BASE

Living Quarters	100,000 lb.
Base Operation, Crew Support, & Logistics Quarters	125,000
Life Support & Environmental Control Systems (20,000) & Supplies (40,000)	60,000
Construction Equipment	80,000
Communications Systems	15,000
Power Station & Power Distribution Equipment	40,000
Observatories & Laboratories	125,000
Scientific Equipt. (110,000) & Supplies (20,000)	130,000
Lunar Surface Vehicles	110,000
Emergency Earth-Return Vehicles (60,000) & Propellants (130,000)	190,000
Miscellaneous Supplies & Equipment	25,000
TOTAL	1,000,000 lb.

TABLE 13

RESUPPLY WEIGHT SUMMARY/MANNED LUNAR BASE

Life Support & Environmental Control Supplies	40,000 lb.
Scientific Equipt. (50,000) & Supplies (10,000)	60,000
Lunar Surface Vehicles, Spare Parts, Fuel, Etc.	30,000
Earth-Return Propellants	345,000
Miscellaneous Supplies & Equipment	25,000
TOTAL	500,000 lb.

TABLE 14

SUMMARY OF FLIGHT SYSTEMS/MANNED LUNAR BASE

Translunar Flight Vehicles

Presupply Cargo Carriers

Saturn 5 Vehicles
35 Required

Lunar Logistic Vehicles
35 Required

Presupply Personnel Carriers

Saturn 5 Vehicles
12 Required

Apollo Command Modules
12 Required

Apollo Service Modules
12 Required

Apollo Lunar Excursion Modules
12 Required

Base Assembly Personnel Carriers

Saturn 5 Vehicles
9 Required

Apollo Command Modules
9 Required

Apollo Service Modules
9 Required

Apollo Lunar Excursion Modules
9 Required

TABLE 14 (Cont'd)

SUMMARY OF FLIGHT SYSTEMS/MANNED LUNAR BASE

Resupply Cargo Carriers

Saturn 5 Vehicles
18 Required

Lunar Logistics Vehicle
18 Required

Base Operation Personnel Carriers

* Saturn 5 Vehicles
10 Required

Apollo Command Modules
10 Required

Modified Apollo Service/Logistic Modules
10 Required.

* First stage off-loaded 1,350,000 lb.

TABLE 15

SYSTEM DESCRIPTION/MANNED LUNAR BASE

LUNAR LOGISTIC VEHICLE

Cargo Module			32,000 lb.
Cargo		28,800 lb.	
Structure		3,200	
Propulsion Module			58,000
Propellants - LO_2/LH_2		48,800	
Residual Propellants		500	
Structure		5,700	
LO_2 Tanks	(700)		
LH_2 Tanks	(2000)		
Interstages & Skirts	(1150)		
Thrust Structure	(200)		
Heat Shield	(50)		
Landing Gear	(1600)		
Propulsion Inert		1,700	
Engines - 2 P&W RL 10A	(650)		
LO_2 Pressurization System	(300)		
LH_2 Pressurization System	(350)		
Engine Controls	(150)		
Plumbing & Accessories	(250)		
Guidance & Navigation		1,000	
Power Supply - H_2 - O_2 Fuel Cells		300	

TABLE 16

SYSTEM DESCRIPTION/MANNED LUNAR BASE

MODIFIED APOLLO SERVICE MODULE

Structure		9000 lb.
Body, Tank Support, Thrust	(3200)	
Landing Gear	(1000)	
Propellant Tanks	(1800)	
Interstage SM/SIV B	(3000)	
Environmental Control System		500
Propulsion System		43,800
Propulsion - N_2O_4/Aerozine - 50	(42,000)	
Engines - 3 at 10.5 K (LEM)	(900)	
Pressurization System	(600)	
Plumbing, Cont. & Accessories	(300)	
Attitude Control System		1,600
Guidance & Navigation		300
Power Supply, Dist. & Cont. - H_2-O_2 Fuel Cells		1800

TABLE 17-a
(1) TRAJECTORY DATA
MANNED LUNAR BASE

CARGO CARRIER

Total One-Way Trip Time (Hrs)	72
Velocity Increments - Lunar Landing (ft/sec x 10^{-3})	
Retro For Lunar Capture Orbit	3.200
Retro For Descent To 1000 Ft. Altitude	6.000
Hover, Translate And Touchdown	1.000
Velocity Increments - Guidance Maneuvers (ft/sec x 10^{-3})	
Outbound	.500

TABLE 17-b

(1) TRAJECTORY DATA
MANNED LUNAR BASE

APOLLO/LEM PERSONNEL CARRIER

Total One-Way Trip Time (Hrs)	72
Velocity Increments - Lunar Landing, Liftoff, Etc. (ft/sec x 10^{-3})	
Retro For Lunar Capture Orbit (100 N.M.)	3.445
Retro For Transfer To Elliptic Orbit	.415
Retro For Descent, To 1000 Ft. Altitude	6.555
Hover, Translate & Touchdown	.770
Launch To Lunar Orbit (50,000 Ft. Perilune)	6.470
Plane Change, Rendezvous & Dock	.410
Reserve For Lunar Orbit Rendezvous (S.M.)	.685
Lunar Orbit Departure	3.970
Velocity Increments - Guidance Maneuvers (ft/sec x 10^{-3})	
Outbound	.330
Inbound	.330

TABLE 17-c

TRAJECTORY DATA

MANNED LUNAR BASE

MODIFIED APOLLO PERSONNEL CARRIER

Total One-Way Trip Time (Hrs)	72
Velocity Increments - Lunar Landing, Liftoff, Etc. (ft/sec x 10^{-3})	3.445
Retro For Lunar Capture Orbit (100 N.M.)	3.445
Retro For Descent To 1000 Ft. Altitude	6.555
Hover, Translate And Touchdown	.770
Launch To Lunar Orbit (100 N.M.)	6.555
Lunar Orbit Departure	3.970
Velocity Increments - Guidance Maneuvers (ft/sec x 10^{-3})	
Outbound	.330
Inbound	.330

6.1 (Cont'd)

Mission Three - Earth Orbiting Manned Space Station

This mission was evaluated on the basis of accomplishing two general objectives: namely; (1) to conduct earth orbit science and engineering experiments;and (2) to support earth orbit assembly, checkout and launch of lunar and/or interplanetary spacecraft. The station was assumed to be manned by 24 personnel, eight of whom would be required for maintaining and operating the station. The remainder of the crew would serve as experimenters, experimental subjects, or technicians in support of assembly and checkout operations. The operational phase of the mission was assumed to be one year in duration with crew rotation every sixty days. Laboratory equipment for science experiments and observations were considered as part of the space station system. Special equipment required in support of assembly, checkout and launch operations was considered as part of the spacecraft being prepared for launch and did not enter into the evaluation. Only the capability to provide life support and protective facilities for the personnel engaged in the latter activities was considered.

The operational mode for this mission entails the launching of the space station into near earth orbit and the subsequent activation, supply and crew rotation functions required during the one-year operation period. At the time of launch the station will be fully equipped with all operating and laboratory hardware. A minimum amount of consumables will also be on board at launch to enable station activation; however, food and water for crew consumption will be supplied on an as-required basis by [illegible] logistic supply vehicles. The logistic vehicles will also provide crew transportation, resupply of consumables, standard equipment for spacecraft assembly operations and spare parts for station facilities.

The constituent vehicles of the space station system are: (1) the space station; (2) a space station launch vehicle; (3) twelve ballistic logistic vehicles and; (4) launch vehicles for the logistic vehicles. A Saturn 5 is used to launch the space station,and Saturn 1B vehicles are used to launch the logistic vehicles. Descriptions of the space station and logistic vehicle are presented in Tables 18 and 19. The logistic vehicle is designed to carry a crew of twelve men in addition to a cargo payload of 10800 pounds to the space station. The reentry module is used for scheduled earth return trips as well as emergency escape. Velocity requirements for all propulsive functions of the vehicle appear in Table 20.

TABLE 18

SYSTEM DESCRIPTION/MANNED SPACE STATION

SPACE STATION		
Structure		131,420 lb.
Modules (3)	(50,030)	
Tubes (6)	(33,990)	
Hub	(47,400)	
Electronics		3,080
Instruments & Panels	(1,150)	
Communications	(1,730)	
Guidance & Navigation	(200)	
Attitude Control System		3,400
Propellant	(2,000)	
Tanks & Plumbing	(1,140)	
Reaction Jets	(260)	
Stabilization Control		2,500
Electrical Power System		34,060
Batteries	(8,320)	
Solar Cells	(24,000)	
Distribution & Control	(1,740)	
Environmental Control		20,910
Thermal Control	(6,400)	
CO_2, H_2O & Odor Control	(1,060)	
Air Sealed At Launch	(2,250)	
Air Tanks & Controls	(10,000)	
Oxygen Regeneration Equipt.	(1,200)	
Science Equipment & Spares		
Personnel Accommodations		1,320
Adapter & Nose Fairing		7,330
Propulsion System		8,500

TABLE 19

SYSTEM DESCRIPTION/MANNED SPACE STATION

BALLISTIC LOGISTICS VEHICLE

Reentry Module			14,150 lb.
Structure		3,230 lb.	
External - Shell, Stringers, Etc.	(1920)		
Internal - Couches, Shock Atten., Etc.	(960)		
Insulation	(350)		
Heat Shield		770	
Environmental Control System		1,290	
CO_2 & Odor Removal System	(140)		
Food, Water O_2, N_2, Etc.	(670)		
Containers, Heat Exchangers ,Etc.	(420)		
Controls	(60)		
Power Supply		1,280	
Fuel Cells	(420)		
Tanks, Heat Exchangers , Etc.	(152)		
Controls & Distribution System	(310)		
Reactants - O_2, H_2	(258)		
Backup Battery	(140)		
Landing System		880	
Parachute	(504)		
Retro Rockets	(200)		
Controls	(176)		
Reaction Control System		1,620	
Engines, Tanks, Controls, Etc.	(500)		
Propellants, Etc.	(1120)		
Communication System		260	
Navigation & Guidance		380	
Controls & Display Instr.		140	
Crew & Suits		2,460	
Retro Propulsion System (Solid)		1,500	
E.C.S. Back Packs		50	
Snorkel & Flotation Systems		110	
Misc. & Syst. Integ. Umbilicals, Etc.		180	

TABLE 19 (Cont'd)

SYSTEM DESCRIPTION/MANNED SPACE STATION

BALLISTIC LOGISTICS VEHICLE

Cargo Module			10,290 lb.
Structure		1,600 lb.	
Propulsion System		8,115	
Engine	(527)		
Propellant Tanks	(536)		
Pressurization System	(179)		
Controls	(23)		
Plumbing	(144)		
Propellants	(6706)		
Reaction Control System		270	
Engines, Tanks, Controls, Etc.	(70)		
Propellants, Etc.	(200)		
Environmental Cont. Syst.		180	
Tanks, Heat Exch'n'g'r, Etc.	(70)		
Coolant	(110)		
Jettison Rocket		20	
System Integration Umbilicals, Etc.		105	
Launch Escape System (Actual)		9,500	

TABLE 20

TRAJECTORY DATA

EARTH ORBITING MANNED SPACE STATION

LOGISTICS SUPPLY

Velocity Increments - Ascent To Space Station (ft/sec x 10^{-3})	
Transfer From 60 N.M. Orbit To 260 N.M. Orbit	.700
Plane Change	.100
Terminal Rendezvous & Docking	.410
Velocity Increments - Descent (ft/sec x 10^{-3})	
Separation From Space Station	.050
Retro For Deorbit	.550

6.1 (Cont'd)

Mission Four - Manned Mars Landing and Return

The Manned Mars mission is a six-man scientific expedition involving a ten-day stopover on the planet's surface. The single-vehicle mission is carried out by use of a Mars orbit rendezvous technique. That is, on arrival in Mars orbit a Mars Excursion Module (MEM) is separated from the main spacecraft. The MEM then de-orbits and lands while the spacecraft continues to circle the planet. The lander uses atmospheric braking for the descent phase with terminal deceleration being provided by parachute. Four of the six-man crew are landed. After a ten-day stay the MEM ascends to orbit for rendezvous with the orbiting spacecraft. After crew transfer the spacecraft departs for earth where atmospheric entry and descent are conducted as in the Apollo program.

The vehicle system defined for this mission will be assembled and checked out in low earth orbit. Five Nova class vehicles will be used to place the required components and propellants in orbit for each flight. The spacecraft consists of:

(1) A Propulsion Module; (2) A MEM; (3) A living compartment; (4) A service Module; and (5) A separate Command Module for earth atmospheric entry.

A fast nuclear reactor provides interplanetary propulsive power; three propulsion systems, each of 150,000 pounds thrust are used for earth departure. Only one of these units is retained after departure. The MEM employs liquid chemical propulsion units which use earth-storable propellants. A more detailed description of the vehicle required for a 357 day mission is provided in Tables 21 through 23.

During the interplanetary trip the spacecraft is rotated to provide approximately 0.4 earth g's. A regenerative life support system is assumed which results in total losses of 2.0 pounds per man day. The living compartment atmospheric pressure is maintained at 10 psia and the compartment is equipped with a storm cellar of 300 cubic feet for protection from solar flares.

The velocities required for the Mars mission are shown in Table 24. Velocities are given for each of three different trip times. The results of the evaluation which are presented in section 7 of this report are for a 357 day mission. Earth orbit weights and performance summaries for 410 and 450 day missions are presented in the appendix of this report. It should be noted that a stay time at Mars of 30 days is required to complete the 450 day trip.

The velocity requirements for this mission and for the Venus mission, described in section 6.4, were obtained by modification of the data from Reference 1 . The procedure used to modify the data is outlined in the appendix.

TABLE 21

SYSTEM DESCRIPTION/MANNED MARS LANDING

COMMAND MODULE - 6 MAN REENTRY		12,500 lb.
Structure	3,000 lb.	
Ablation Material	2,000	
Insulation	500	
Water	500	
Water Tankage & Plumbing	50	
Navigation & Guidance Equipment	350	
Communications, Instruments & Displays	700	
Power Supply & Distribution	600	
Attitude Control System	600	
Environmental Control	800	
Earth Landing System	1,200	
Scientific Equipment	360	
Mars Sample	40	
Crew Furnishings	600	
Crew (6)	1,200	
SERVICE MODULE		16,500
Structure	1,500	
Power Supply 6 KW Nuclear	2,200	
Electronics	300	
Attitude Control System - Thrusters,Etc.	600	
Attitude Control - Propellant	1,200	
Food	7,100	
H_2O closed systems	400	
O_2	300	
N_2	600	
Fluid Storage & Regeneration Equipment	1,100	
Temperature & Humidity Control	1,000	
Contamination Control	200	

TABLE 21 (Cont'd)

SYSTEM DESCRIPTION/MANNED MARS LANDING

STORM CELLAR & LIVING QUARTERS		26,000 lb.
H_2O Proton Shielding	20,000 lb.	
Structure	4,000	
Crew Furnishings, Rec. Equipment, Sleeping Area	1,200	
Environmental Equipment	600	
Intercom. & Misc. Equip.	200	
TELESCOPING SPOKES (2)		4,000
Length = 75', Dia. = 4'		

TABLE 22

SYSTEM DESCRIPTION/MANNED MARS LANDING

MARS EXCURSION MODULE

Descent Stage			15,300 lb.
Structure		1,860 lb.	
Landing Gear		1,500	
Parachute System		4,000	
Drag Device - Deployed During Atmospheric Entry		1,020	
Heat Protection		1,000	
Environmental Control System		1,220	
Food	(120)		
Water	(300)		
O_2	(180)		
N_2	(40)		
Tankage, Plumbing, Storage	(250)		
Odor, & CO_2 Removal	(170)		
Radiators, Pumps, Etc.	(160)		
Power Supply - Fuel Cells (3KW)		1,900	
Communications & Instrumentation		800	
Scientific Equipment		2,000	
Ascent Stage			34,800
Structure - Crew Compartment		1,330	
Power Supply & Distribution		500	
Electronics		700	
Propulsion		2,300	
Engine(T = 25K lb)	(600)		
Tanks & Sup'ts.	(780)		
Structure	(800)		
Plumbing & Controls	(120)		
Environmental Control, Food, Water		450	

TABLE 22 (Cont'd)

SYSTEM DESCRIPTION/MANNED MARS LANDING

Ascent Stage (Cont'd)

Attitude Control System (Incl. 600 lb. Propellant)	1,100 lb.
Mars Soil Sample (Return Trip)	(40)
Propellant - N_2O_4/Aerozine	27,040
Crew Provisions	580
Crew (4)	800

TABLE 23

SYSTEM DESCRIPTION/MANNED MARS LANDING

PROPULSION MODULE (357 day trip)	1,731,900 lb.
Reactor Core & Reflector (3 x 1300)	3,900 lb.
Shield (Primary), Pressure Vessel & Plumbing (3 x 650)	1,950
Nozzle (3 x 5000)	15,000
Pumps & Turbines (3 x 310)	930
Controls & Misc. (1680)	1,680
Valves (990)	990
Shadow Shield (3x 1350)	4,050
Support Structure (1500)	1,500
Propellants	1,466,540
Propellant Tanks	229,000
Attitude Control	6,360

NOTE:
1. Core Power = 3000 MW.
2. Engine Thrust = 50 x 3000 = 150,000 LB.
3. Operating Temperature = $5000^{o}R$
4. I_{SP} = 900 LB_T/LB_{LH_2}/SEC.
5. Nozzle Expansion Ratio = 100/1

TABLE 24

TRAJECTORY DATA

MANNED MARS LANDING & RETURN

	EARLY	NEAR OPTIMUM	LATE
Earth Departure Dates			
First Flight	4-15-83	4-29-83	5-29-83
Second Flight	4-22-85	5-6-85	6-5-85
Total Trip Time (Days)	450	410	357
Velocity Increments - Transfer, Launch, Etc. (ft/sec x 10^{-3})			
Earth Orbit (200 N.M.) Departure	33.8	31.3	29.2
Retro For Capture Orbit (100 N.M.)	16.4	15.3	18.1
Retro For Deorbit	0.4	0.4	0.4
Launch Into Orbit & Rendezvous	15.0	15.0	15.0
Mars Orbit Departure	12.0	13.0	16.6
Retro For Earth Reentry (100 N.M. Alt.)	1.2	1.35	3.0
Velocity Increments - Guidance Maneuvers (ft/sec x 10^{-3})			
Outbound	1.0	1.0	1.0
Inbound	1.0	1.0	1.0

6.1 (Cont'd)

Mission Five - Unmanned Sample Return From Venus

For the purpose of this evaluation the Venus mission was assumed to entail only those engineering functions essential to the acquisition and return of a one-pound sample. The possibility of making scientific measurements enroute or on the planet's surface was not considered since it was assumed that information acquired from previous scientific probes was sufficient to support this more ambitious venture.

The mission evaluation was based on the use of an unmanned Venus orbit rendezvous technique. On arrival in Venus orbit, an unmanned Venus Excursion Module, (VEM), is separated from the main vehicle for descent to the planet's surface. The VEM deorbits and uses atmospheric braking for descent; terminal deceleration is provided by parachute, enabling a soft landing. After sample acquisition, the liftoff stage of the VEM provides propulsive power for launch and for rendezvous with the orbiting vehicle. The earth-return flight is terminated by direct atmospheric entry and earth-surface retrieval of the sample. A total stay-time of ten days was allowed in the vicinity of the planet because of the extremely accurate tracking requirements and complex guidance maneuvers needed to effect efficient deorbit and subsequent rendezvous of the VEM.

A brief description of the vehicle system postulated for the Venus mission appears in Tables 25 through 28 . A fast nuclear reactor propulsion module is used for interplanetary transfer in both the outboard and inbound legs of the journey. Only one engine is provided in the module, requiring that the unit be throttleable for earth return. Other units comprising the vehicle system are the Venus Excursion Module and Instrumentation Unit. The earth return spacecraft is a sub-unit of the VEM. The Venus vehicle is assembled in earth orbit. Launching the required modules into earth orbit will be accomplished by two Nova class vehicles. An earth orbit space station will be required in support of assembly and launch operations.

The velocity requirements for the mission are shown in Table 29 . Data are given for trip times of 460, 420 and 332 days. In order to complete the 460 day mission a stay-time of 20 days would be required in the vicinity of the planet. These velocity data were obtained in the same manner as those presented in section 6.1.3 for the Mars mission.

TABLE 25

SYSTEM DESCRIPTION SAMPLE RETURN FROM VENUS

VENUS EXCURSION MODULE			183,200 lb.
Retro Stage		20,200 lb	
Structure & Insulation	1,300 lb.		
Engine - 40. K	800		
Plumbing, Hydraulic & Pneumatic	100		
Navigation & Guidance	200		
Power Supply - Battery, Inverter, Wiring, Etc.	150		
Propellant - N_2O_4/Aerozine 50	17,650		
Landing Stage		27,200	
Structure - Device For Increasing Frontal Area (including Heat Shield)	13,600 lb.		
Structure - Landing Gear	5,400		
Parachutes	8,080		
Sampler	120		
Launch Vehicle			
1st Stage		90,790	
Structure & Insulation	4,800 lb.		
Engine (s) 200 K	2,800		
Plumbing, Hydraulic & Pneumatic Systems	200		
Guidance & Control	200		
Power Supply - Batteries, Wiring, Etc.	300		
Propellant - N_2O_4/A-50	82,490		
2nd Stage		35,770	
Structure & Insulation	2,500 lb.		
Engine - 40 K	800		
Plumbing	150		
Power Supply & Distribution	150		
Guidance & Control	200		
Propellant - N_2O_4/A-50	31,970		

TABLE 25 (Cont'd)

SYSTEM DESCRIPTION/SAMPLE RETURN FROM VENUS

3rd Stage - Used For Rendezvous		7,830 lb.
Structures & Insulation	400 lb.	
Engine (s) - 5K (Throttlable)	120	
Plumbing	50	
Power Supply - Batteries & Wiring	300	
Navigation & Guidance Equipment	1,000	
Propellant - N_2O_4/A-50	5,960	
SPACECRAFT		1,110
SPACECRAFT SHROUD & ADAPTER		300

TABLE 26

SYSTEM DESCRIPTION/SAMPLE RETURN FROM VENUS

SPACECRAFT (At Start Of Transearth Phase)			1,110 lb.
Midcourse Correction Stage		160 lb.	
Structure & Plumbing	26 lb.		
Engine (T = 200 lb)	10		
Propellant - Storable	124		
Retro Stage		150	
Case & Nozzle	45		
Propellant	105		
Re-Entry Module		800	
Structure	150		
Sample Container & Retrieval Mechanism	50		
Power Supply - Solar Panels & Batteries	100		
Navigation & Guidance	200		
Communication	100		
Reaction Control Syst. (incl. 30 lb Prop.)	60		
Reentry System - Heat Shield	80		
- Parachutes & Impact Attenuation	60		

TABLE 27

SYSTEM DESCRIPTION/SAMPLE RETURN FROM VENUS

INSTRUMENT UNIT		3,500 lb.
Structure	1,500 lb.	
Environmental Control System	400	
Navigation & Guidance Equipment	800	
Communications Equip.	400	
Power Supply - Conversion Equip., Etc.	400	

TABLE 28

SYSTEM DESCRIPTION/SAMPLE RETURN FROM VENUS

PROPULSION MODULE (420 day trip)		719,250 lb.
Reactor Core & Reflector	1,620 lb.	
Shield, Pressure Vessel & Plumbing	950	
Nozzle	6,300	
Pumps & Turbines	420	
Controls & Misc.	560	
Valves	430	
Shadow Shield	1,920	
Support Structure	300	
Propellants	585,000	
Propellant Tanks	118,150	
Attitude Control	3,600	

NOTES:

1. Core Power = 4000. Megawatts
2. Engine Thrust = 50 x 4000 = 200,000 LB (Throttlable to 100,000 lb with negligible loss in I_{SP})
3. Operating Temperature = 5000 $^{\circ}$R
4. I_{SP} = 900 Sec.
5. Nozzle Expansion Ratio = 100/1

TABLE 29

TRAJECTORY DATA

UNMANNED SAMPLE RETURN FROM VENUS

	EARLY	NEAR OPTIMUM	LATE
Earth Departure Dates			
First Flight	11-27-77	12-27-77	2-25-78
Second Flight	6-29-79	7-29-79	9-27-79
Third Flight	2-3-81	3-5-81	5-4-81
Total Trip Time (Days)	460	420	332
Velocity Increments - Transfer, Launch, Etc. (ft/sec x 10^{-3})			
Earth Orbit (200 N.M.) Departure	20.3	19.4	18.5
Retro For Capture Orbit (100 N.M.)	12.8	12.0	12.4
Retro For Deorbit	1.0	1.0	1.0
Launch Into Orbit & Rendezvous	30.0	30.0	30.0
Venus Orbit Departure	9.9	10.4	15.6
Retro For Earth Reentry (100 N.M. Alt.)	1.0	1.0	3.1
Velocity Increments - Guidance Maneuvers (ft/sec x 10^{-3})			
Outbound	1.0	1.0	1.0
Inbound	1.0	1.0	1.0

6.2 Development Plans

Brief development plans and identification of long lead time development items will now be presented for Missions Two through Five.

6.2.1 Manned Lunar Base

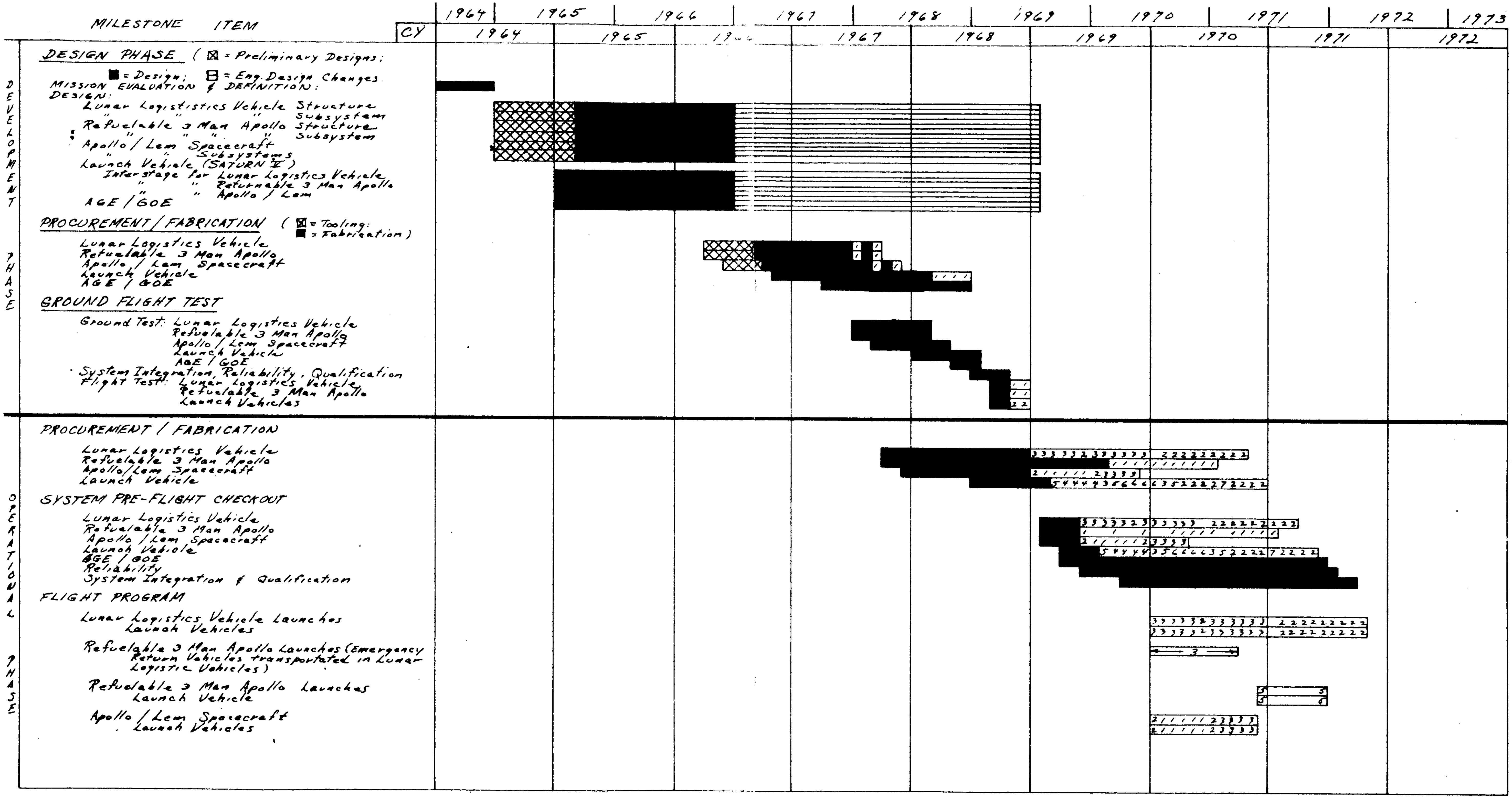
A brief development plan for the Manned Lunar Base mission is presented in Figure 14. The achievement of operational status by the system candidate requires the development of the following long-lead-time items.

1. Lunar Logistics Vehicle
2. Modified Apollo Service Module
3. Lunar Surface Roving Vehicles

ADVANCED MISSION ANALYSIS
LUNAR BASE DEVELOPMENT PLAN

FIGURE 14

DATE PREPARED 28, AUGUST 1963



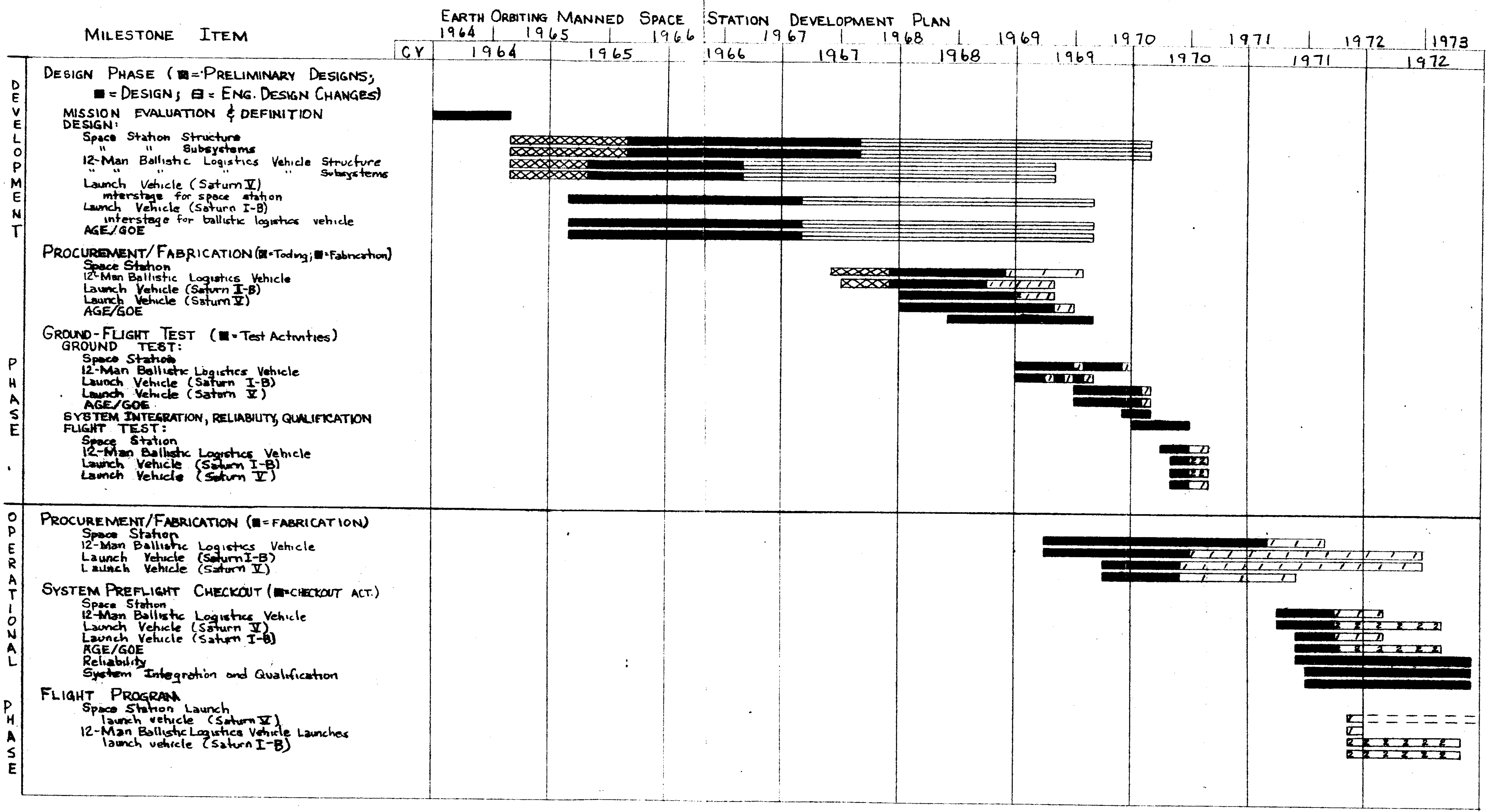
6.2.2 Earth Orbiting Manned Space Station

Figure 15 shows a brief development and operational plan for the space station mission.The long-lead-time development items are:

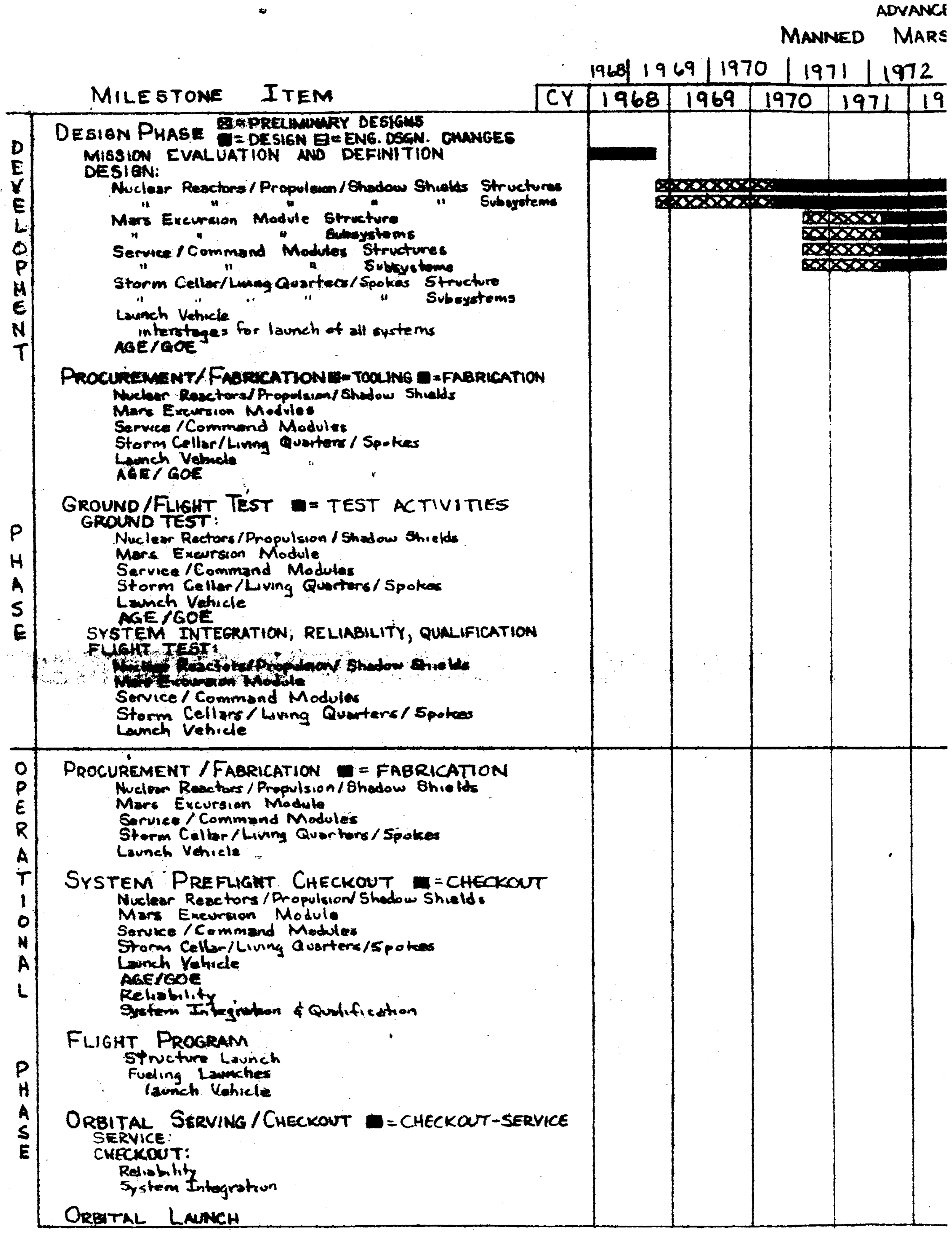
1. Space Station
2. Ballistic Logistic Vehicle
   a. Cargo Module
   b. Reentry Module
3. Auxiliary Power Unit, 40 KW, for the station.

FIGURE 15

ADVANCED MISSIONS ANALYSIS



NOTE: NUMBERS INDICATE COMPLETED FABRICATION, TEST, CHECKOUT, OR LAUNCH OF DEVELOPMENT AND OPERATIONAL SPACECRAFT.
THE LOCATION INDICATES APPROXIMATE COMPLETION TIME AND QUANTITY.



6.2.3 Manned Mars Landing and Return

Figure 16 shows a brief development and operational plan for the Mars mission. The long-lead-time development items are:

1. Fast Nuclear Reactor Propulsion Unit
2. Regenerative Life Support System
3. Nova Class Launch Vehicle
4. Operational Earth Orbiting Space Station
5. Mars Excursion Module
   a. Mars Entry System
   b. Parachutes & Landing Gear
   c. Propulsion System for Mars launch.
6. Command Module
7. Service Module

6.2.4 Unmanned Sample Return From Venus

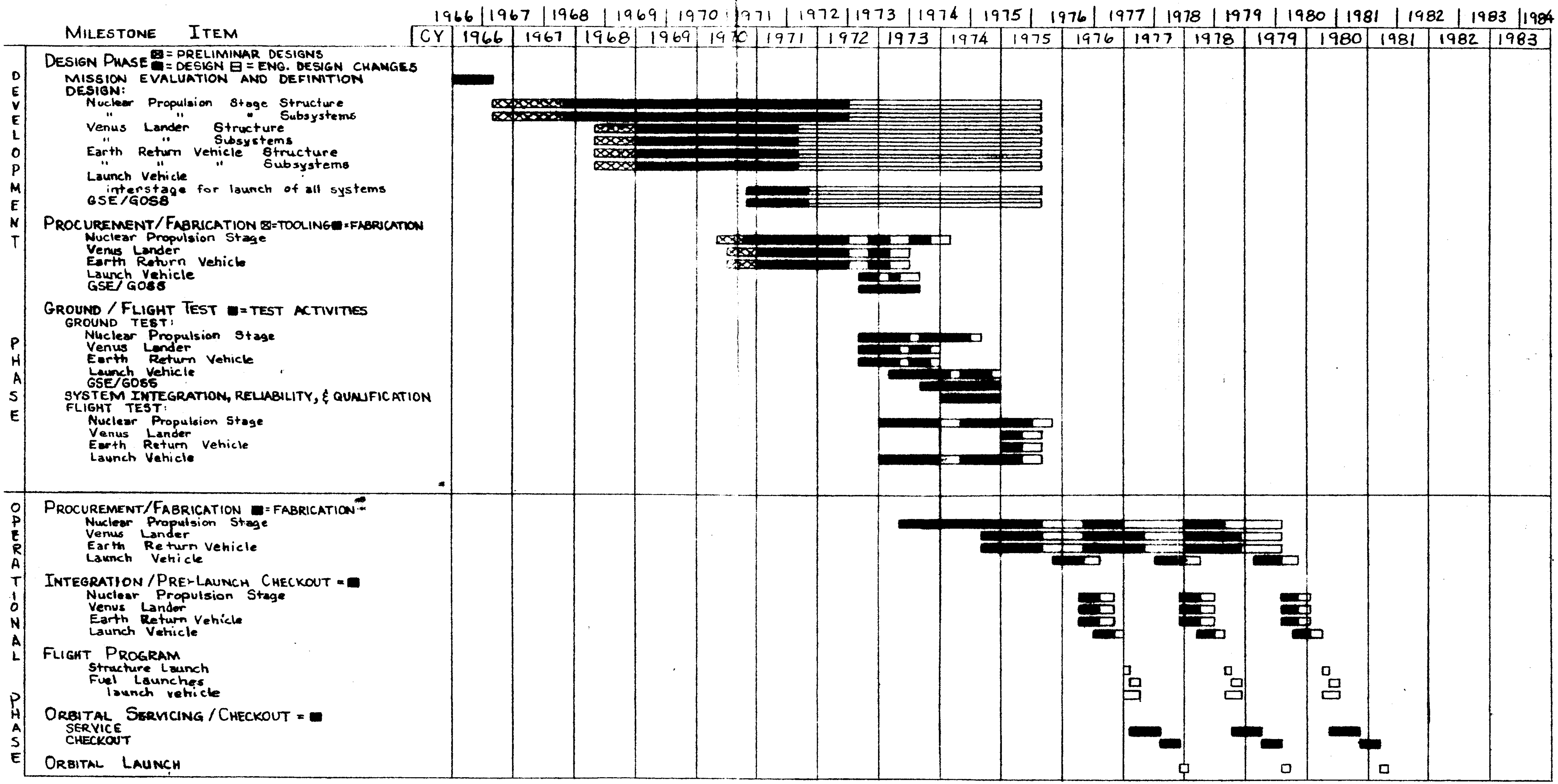
Figure 17 shows a brief development and operational plan for the Venus mission. The long-lead-time development items are:

1. Fast Nuclear Reactor Propulsion Unit - Throttleable
2. Nova Class Launch Vehicle
3. Operational Earth Orbiting Space Station
4. Venus Excursion Module
    a. Venus Entry System
    b. Parachutes & Landing Gear
    c. Propulsion System for Venus Launch
5. Earth Return Spacecraft
6. Guidance & Navigation System for Unmanned Rendezvous in Venus Orbit.

FIGURE 17

ADVANCED MISSION ANALYSIS

UNMANNED VENUS LANDING AND RETURN DEVELOPMENT PROGRAM



NOTE: NUMBERS INDICATE COMPLETED FABRICATION, TEST, CHECKOUT, OR LAUNCH OF DEVELOPMENT AND OPERATIONAL SPACECRAFT. THE LOCATION INDICATES APPROXIMATE COMPLETION TIME AND QUANTITY.

7.0 SUMMARY OF THE MISSION EVALUATIONS

Attention is invited to Table 30, showing a tabulation of the missions considered and the appropriate data for calculating the Mission Evaluation Criterion.

SUMMARY OF THE MISSION EVALUATIONS

TABLE 30

MISSION	PROBABLE MISSION RETURN	COST	SYSTEM PERFORMANCE INDEX	RELATIVE VALUE OF MISSION	MISSION EVALUATION CRITERION
	% OF MISSION ACHIEVEMENT, DIML'S	$, 10^9	$\frac{\text{DIML'S}}{\$}$, 10^9	DIML'S	$\frac{\text{DIML'S}}{\$}$, 10^9
			1/2		3 x 4
Jupiter Probe	21.32	1.002	21.20	1.00	21.20
Lunar Base	41.10	21.48	1.91	2.63	5.03
E.O. Space Station	45.28	2.80	16.18	2.40	38.80
Mars Landing & Return	45.19	18.21	2.48	3.22	7.98
Venus Sample Return	23.03	14.79	1.56	.69	1.08

8.0 REFERENCES

1. Gedeon, Geza S., "RoundTrip Trajectories to Mars and Venus," Technical Memorandum NSL 62-83, Northrop Space Laboratories (May 1962).

2. "Launch Vehicle Size and Cost Analysis Study, Phase III, Part I Cost Analysis, Volume II Cost and System Evaluation," 8659-6056-RU-000, Space Technology Laboratories, Inc., for NASA, MSFC, Contract No. NAS 8-2599 (December 1962).

3. "Summary Report Early Manned Interplanetary Mission Study, Volume I," Lockheed Missiles and Space Co., for NASA, MSFC, Contract No. NAS 8-5024 (March 1963).

4. Straly, W. H. and Voss, R. G., "Basic Requirements for the Exploration of Jupiter and its Moons," Report DSP-TR-1-60 Army Ballistic Missile Agency, Redstone Arsenal (March 1960).

5. "Reliability Assessment of the Mariner Spacecraft," PRC R 293, Planning Research Corporation, for Jet Propulsion Laboratory, Contract No. BU3-213751 (December 1962).

6. V. C. Clarke; "A Summary of the Characteristics of Ballistic Interplanetary Trajectories", 1962-1977; JPL TR 32-209; January 15, 1962.